AN EXPERIMENT IN MODIFYING OBJECTIVE 500-mb CONTOUR ANALYSES USING TIROS IX NEPHANALYSES

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Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
METEOROLOGY

United States Naval Postgraduate School
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ABSTRACT

One of the numerical operational products of the United States Navy Fleet Numerical Weather Facility (FNWF) is the objective analysis of 500-mb contours on a hemispheric basis. Up to mid 1965, this analysis has been accomplished without use of weather-satellite observations. The period of 14 thru 20 February 1965 is selected as an experimental test period for the purpose of modifying the FNWF 500-mb analyses in the sparse-data region of the central North Pacific Ocean at 00Z. Synoptic scale phenomena depicted on Tiros IX nephanalyses are used as basis for the analysis modification. Modified 24- and 48-hour prognoses are made and verified. Results are interpreted in light of the experimental nature of the project, restricted time interval selected and experience level of the authors in the field of satellite meteorology.

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ABBREVIATIONS

1. FNWF: United States Navy Fleet Numerical Weather Facility, Monterey, California

2. FAMOS: Fleet Applications of Meteorological Observations from Satellites

3. RMSE: Root Mean Square Error

4. USWB: United States Weather Bureau

SECTION I

Introduction

It has long been recognized that accurate analysis of the circulation patterns at free-atmospheric levels over the vast reaches of the Pacific Ocean has suffered due to an inadequate number of regularly-reporting radiosonde stations.

The hypotheses of the experiment reported on here are:

(1) That subjective modifications of 500-mb contour analyses, based on Tiros nephanalyses, can result in significant improvement of objective analyses using only conventional radiosonde data, and

(2) That novices (i.e. students with no formal training in satellite meteorology) can be successful in such analysis modifications.

Although the second hypothesis is not primary, it is nevertheless a necessary consideration in the case of the investigators performing the experiment.

It would have been desirable to use Tiros photographs in conjunction with the United States Weather Bureau's (USWB) nephanalyses but unfortunately the pictures arrived too late to be used in the experiment.

SECTION II

Background

Several studies (for example 1, 2, 3, 4, 5 and 6) have been completed which conclude that Tiros day-time cloud photographs do reveal sufficient detail to materially aid in subjective analysis of synoptic-scale flow patterns in areas nearly void of conventional meteorological data. The implied application to analysis contained in these references has been used by the authors to carry out the intent of the experiment. For example, features typically seen in the photographs such as cloud vortices, crescent or comma shaped cloud patterns, cloud masses, bands and lines allow supplementation of conventional radiosonde data.[1]

One set of particularly useful analytical rules, based on subjective interpretation of Tiros photographs, has been compiled by Thompson, Cronin, and Kerr (2). Some of the more pertinent "rules" are summarized below (paragraphs A-C) to serve as background for <u>500-mb analysis modifications</u>.

A. <u>Vortices</u>

1. Well defined cloud vortices are indicative of closed-contour systems up to the 500-mb level. Not all 500-mb or surface lows reveal vortices, however. The temporal disappearance of cloud-vortex patterns are strongly indicative of changes in the 500-mb pattern from closed lows to troughs.

[1]Definition of terms used in connection with interpretation of weather-satellite nephanalyses may be found in Appendix 1, reprinted from [7].

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2. The early stages of 500-mb vortex development and the final stages are often very similar, both exhibiting an unorganized cloud structure.

B. Cloud Bands

1. Frontal bands oriented east to west are essentially parallel to the flow at 500 mb.

2. When the 500-mb flow is more nearly normal than parallel to a cold front in the westerlies, the frontal cloud band is on the warm air side of the surface position of the front. Conversely, the cloudiness is mostly on the cold-air side when the flow aloft parallels the front.

3. Transverse striations, elongated along the short axis of frontal bands, are indicative of middle-high cloudiness and are nearly normal to the flow at 500 mb.

4. Long thin streaks parallel to and superimposed upon the frontal band are also indicative of mid-tropospheric cloudiness and tend to be aligned parallel to the 500-mb flow. The streaks are much longer and wider than the transverse striations.

C. Cloud Masses

1. The 500-mb flow tends to parallel the warm edge of a cloud mass.

2. Streaks, well organized and of synoptic scale, on the east side of a cloud mass are imbedded in anticyclonic flow and the 500-mb ridge can be placed just west of the streaky area.

In addition, reference (9) contains several pertinent "rules" regarding trough, ridge and jet stream phenomena. A brief summary (paragraphs D-G) is given below.

D. <u>500-mb Trough</u>

1. The nephanalysis may clearly indicate a fork in a frontal band. A 500-mb trough overlies the front at the apex of the fork.

2. Where the nephanalysis indicates a change in character of the frontal cloud band from covered to mostly covered, a 500-mb trough overlies the demarcation line.

E. <u>500-mb Ridge</u>

1. The nephanalysis may show a broad band in the westerlies ending abruptly downstream or with the cloud character changing on the downstream end from stratiform to cirriform. This line of demarcation usually represents the 500-mb ridge line.

F. <u>500-mb Wind Flow</u>

1. Striations in middle clouds are generally indicators of the flow near the upper portion of the cloud layer.

G. <u>Jet Streams</u>

1. When transverse waves are indicated on the nephanalysis within the general area of the tropical jet stream, the jet should be placed along the poleward edge of the wave.

2. The presence of a polar jet stream is suspected along a line separating fine cells on the cool side from inversion-dominated cells on the warm side. Anticyclonic curls are also found on the immediate warm side of the jet axis.

SECTION III

Data

Tiros IX was placed in orbit 22 January 1965 and continues to function as originally programmed [8]. This is a near-polar orbited, sun-synchronized, space-oriented satellite which provides once-a-day overlapping photographic coverage of practically the whole earth and/or its cloud systems. The period of orbit (approximately 120 minutes) and the chosen launch time made it possible to have the satellite's passage over any given spot on the globe at approximately 2:00 A.M. and P.M. local time. Tiros IX carries two cameras mounted on the rim. It moves northward over the sunlit side of the earth and southward over the dark side. The satellite rotates ten times a minute, allowing the earth to be photographed a maximum of twenty times each minute on the earth's sunlit side.

The central North Pacific Ocean was chosen as the most suitable area for modification of the U. S. Navy Fleet Numerical Weather Facility (FNWF) 500-mb analysis since it is unquestionably a sparse-data area (about six radiosonde stations), and the time of Tiros IX passage is close to the 00Z synoptic observation time.

Pre-selected for the experiment was a period for which Tiros IX data would be available, but yet a few weeks after its launch in order not to suffer from problems normally occurring within the first week of a weather satellite's existence.

Moreover, it was desirable to select a winter period and one which fell near mid-month so that, hopefully, the 500-mb patterns would be representative of the month itself. Thus, the period selected for study was 14-20 February 1965.

SECTION IV

Procedures

1. The USWB nephanalyses were reviewed and the major features of the 500-mb pattern such as troughs, ridges, and closed lows were subjectively located using techniques suggested by references (1) through (6).

2. These features were viewed in register with the original FNWF 500-mb analysis of approximately the same synoptic time.

3. Using acetate overlays, the FNWF analysis was recontoured so as to more closely conform to the major features as shown by the Tiros nephanalysis. Care was taken not to violate data from reliable reporting stations such as Kodiak, Adak, Midway Island, and Ocean Station Ships November, Papa, and Victor.

4. The original FNWF analysis was considered the initial guess field for subjective reanalysis; heights in the original objective analysis were changed as necessary. Such changes were restricted to mostly whole numbered I, J grid points of the FNWF 1:20,000,000 Polar Stereographic Projection map. The changes were applied at centers, troughs, ridges and inflection points, in maximum gradient areas and at other meteorologically significant points in the flow pattern.

5. The modified 500-mb heights were converted to D values using 5574 meters as the "Standard Height" of the 500-mb level. The I, J grid points, with their respective modified D values, were converted to octal numbers and a flex tape was prepared for processing on FNWF's Control Data Corporation 1604 Computer.

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6. A program was written that extracts the 500-mb analysis for the desired date and time from the FNWF master tape, injects the modified D values at the specified points, and makes a smoothed reanalysis of the 500-mb height pattern. This objectively reanalyzed height pattern was then compared to the subjective reanalysis to determine how well the two analyses compared with each other. If the numerical analysis did not closely conform to the subjectively derived pattern, heights at additional I, J grid points were changed and the entire process repeated until a satisfactory Tiros-modified objective reanalysis was produced.

7. Next, FNWF's current barotropic 24- and 48-hour prognoses programs were applied to the Tiros-modified 500-mb height analyses.

8. Finally, prognostic erros for modified and original contour fields were compared and root-mean-square errors (RMSE) determined.

Section VI contains the results of statistical verifications of prognoses.

SECTION V

Case Studies

The figures showing analyses, prognoses and verifications dependent on each of the modified 500-mb analyses follow immediately after the detailed word description of the modifications. For example, discussion of modifications on 14 February 1965: see figures 1 - 5.

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[illegible]

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DISCUSSION OF MODIFICATIONS ON 14 FEBRUARY 1965

A closed 500-mb low center was placed near the Aleutian cloud vortex because of the orientation of the frontal band and striations, and since the spiraling cloud mass about the vortex appears to fit the definition of a mature occluded system. The trough associated with this vortex was sharpened and deepened considerably immediately south of the vortex, in order to better conform to the apparent stage of development as seen in the nephanalysis; this adjustment tightened the gradients along the northwestern edge of the band, thereby locating a portion of the jet stream along the dry-air groove.[2] The ridge to the southwest of the vortex was changed considerably to give more anticyclonic flow in the clear area.

The trough associated with the westernmost vortex complex south and east of Kamchatka (henceforth called vortex "A") was reoriented slightly with its southern portion trailing off more to the southwest. This allowed a tightening of the gradient upstream of the West-Pacific trough near 40N to agree with the cloud extension there downstream from the ridge near northern Japan. In addition, the significant cloud mass near 27.5N, 160E, oriented ENE-WSW, is better accounted for in gradient and curvature of contours.

[2]In this case the so-called dry-air groove of the occluded cyclone is clouded, typical of wave developments over oceans.

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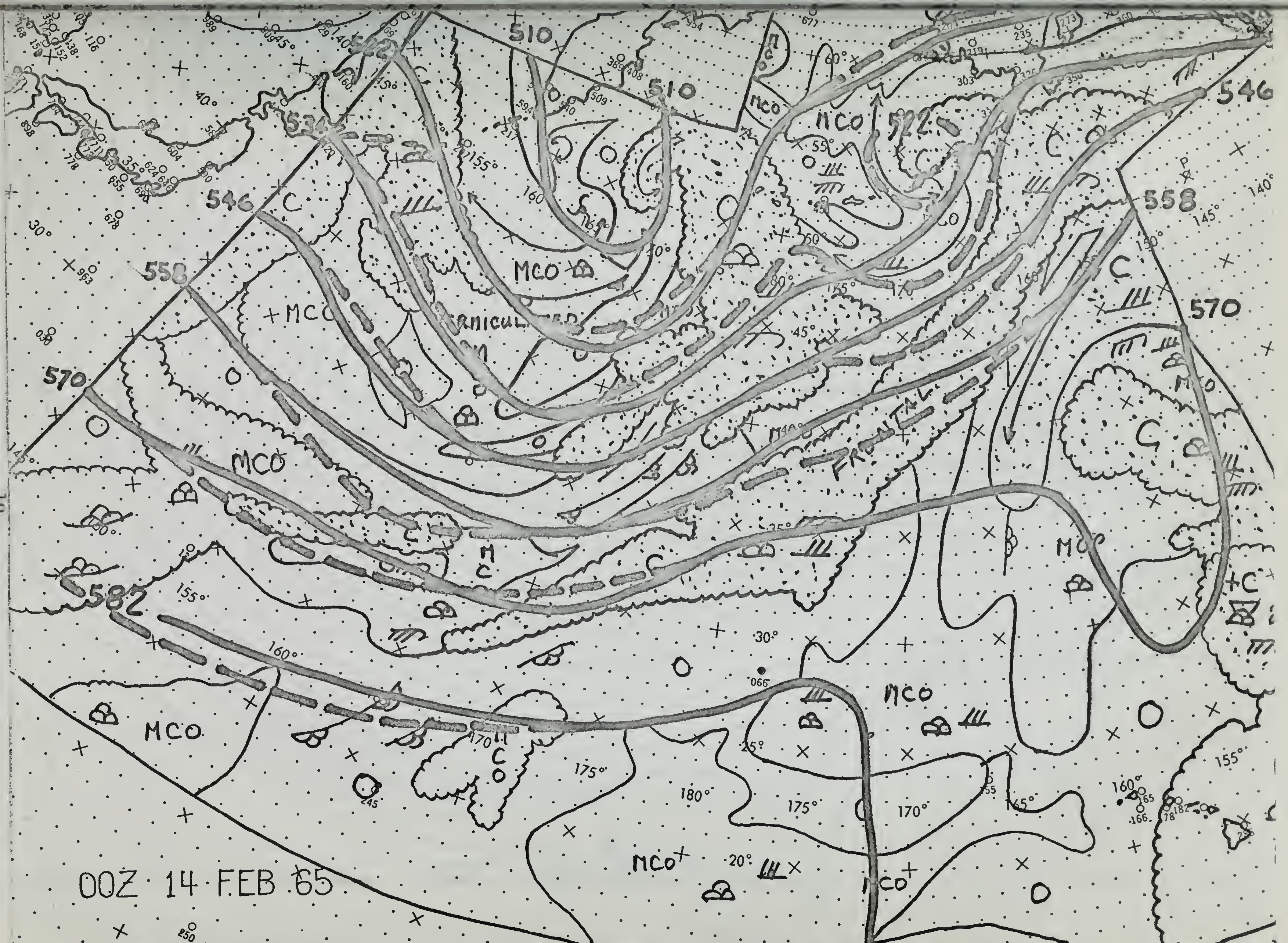
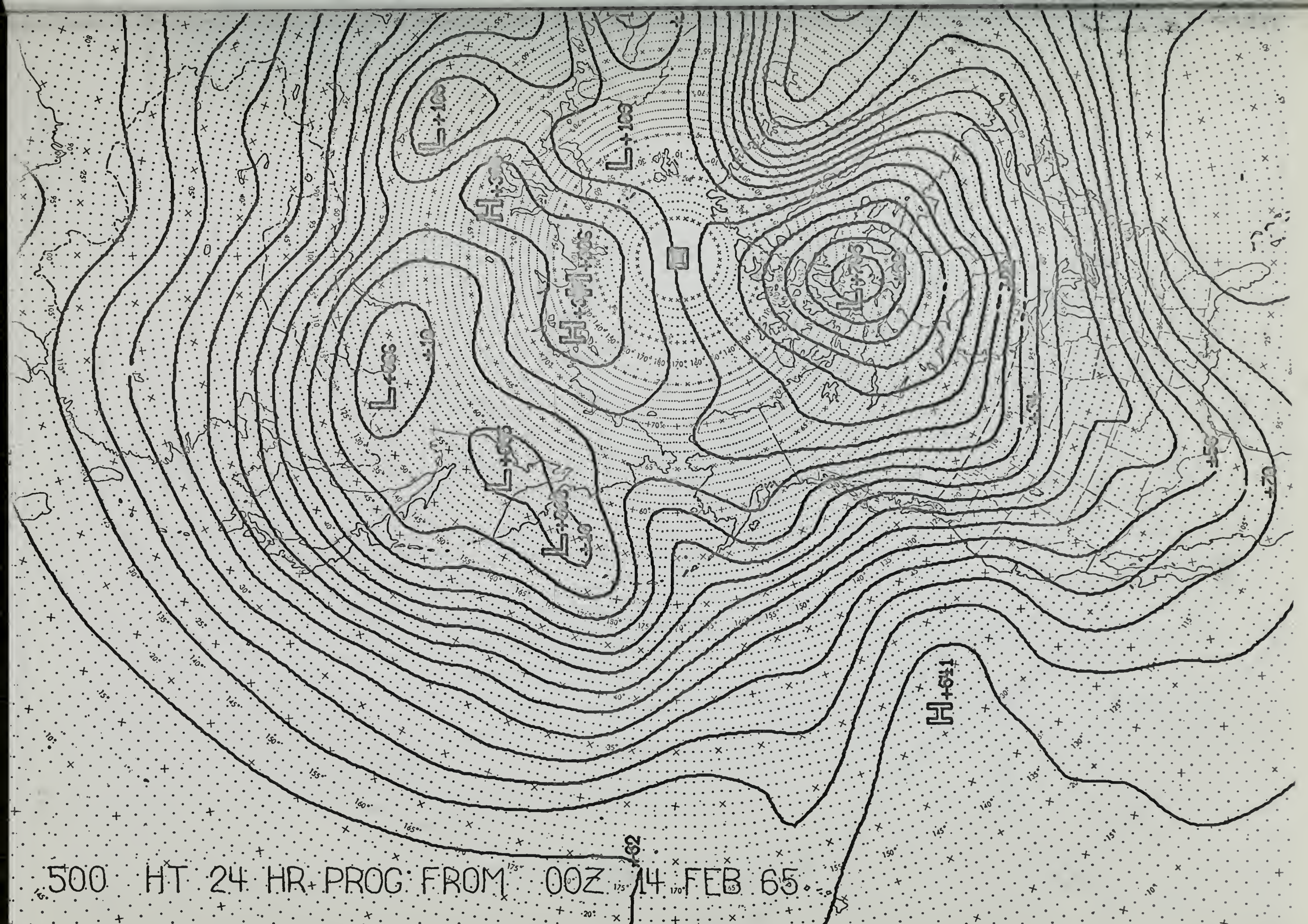


Fig. 1



500 HT 24 HR PROG FROM 00Z 14 FEB 65

Fig. 2

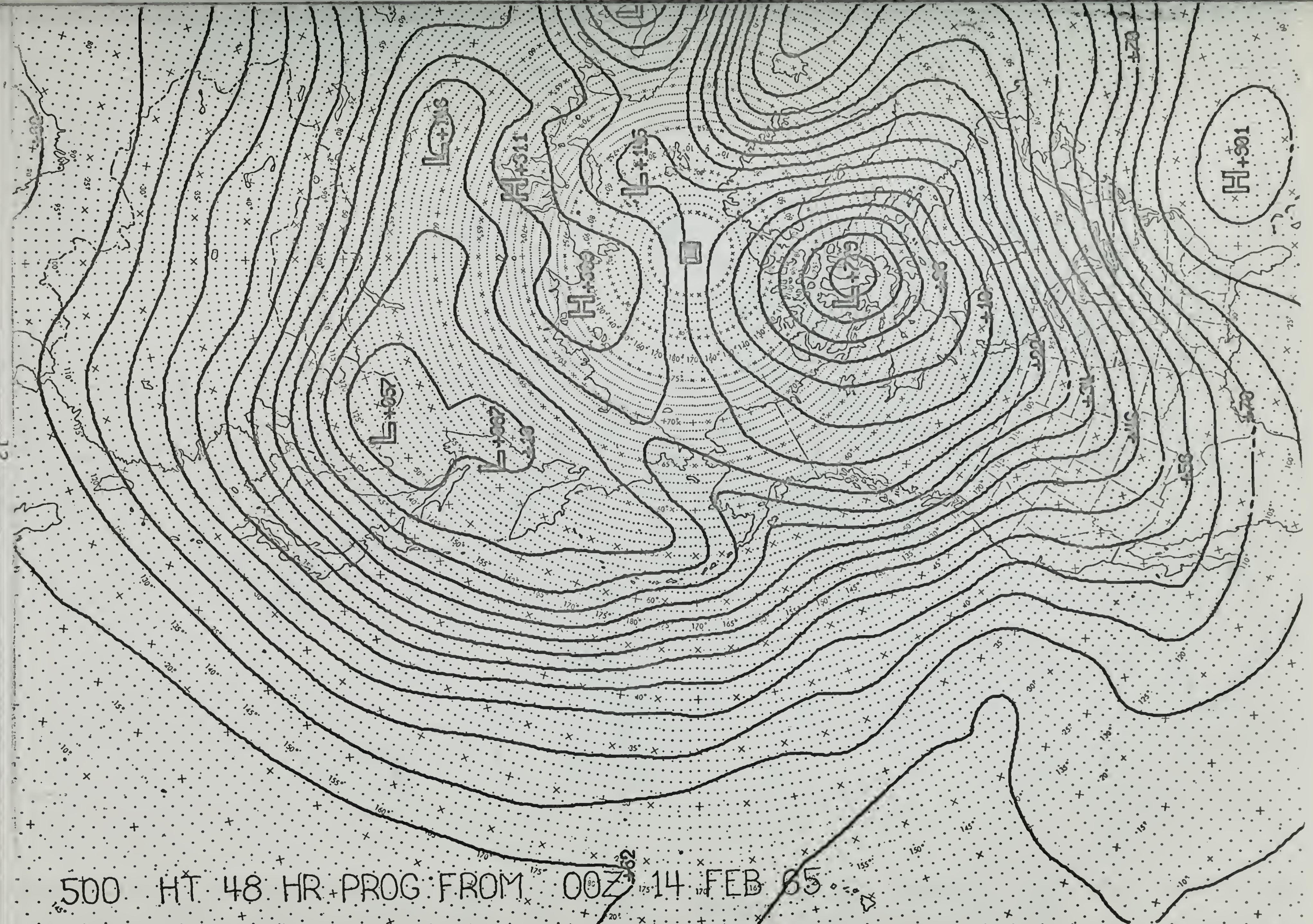
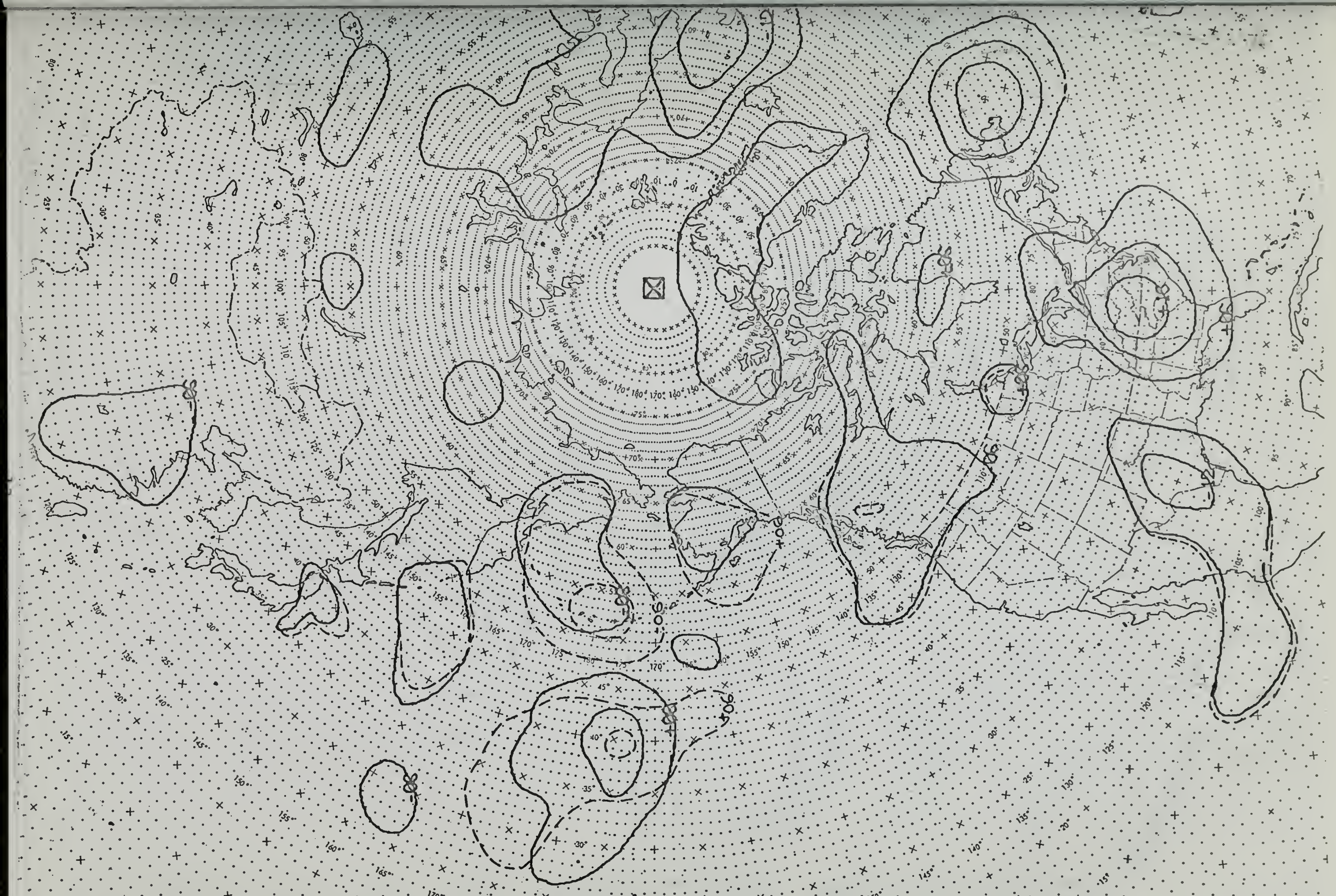


Fig. 3



U 500 24F 24HR 00Z 14 FEB - ANAL 00Z 15 FEB 65

Fig. 4

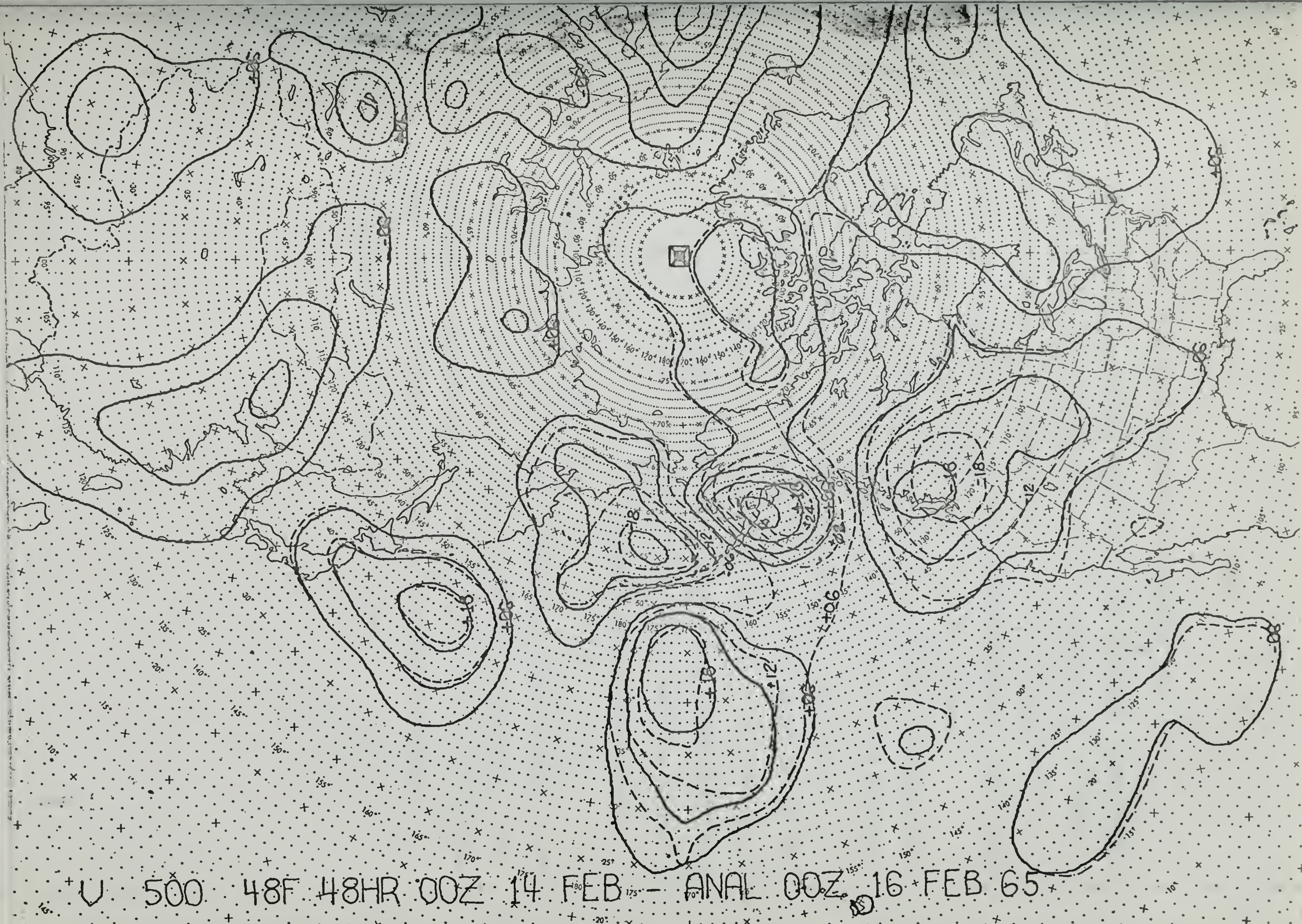


Fig. 5

DISCUSSION OF MODIFICATIONS ON 15 FEBRUARY 1965

A closed 500-mb low center over Alaska was inserted on the basis of history, associated cloud patterns south of Alaska, and on hind-sight after looking at the nephanalysis and contour analysis for 16 February. The associated trough was deepened slightly. This closed low was associated with the Aleutian vortex on 14 February.

Vortex "A" on 14 February is not visible on 00Z 15 February but a look at 16 February shows that a fully-developed vortex has appeared at 45N 171W. When carrying out this experiment, the authors did not attempt to utilize surface analyses, however, in the light of the surface analyses for the period 14 through 16 February, it is very unlikely that the fully-developed vortex of 16 February is a continuation of vortex "A". Vortex "A" has, most likely, ceased to exist as a separate entity on 15 February. This was not apparent when looking only at the 500-mb analyses and the nephanalyses.

The trough associated with the frontal band south and west of the Aleutians was moved eastward to place it more nearly parallel to the frontal cloud band, and to cross the frontal cloud band near the fork at 32N 178W. This trough was also deepened slightly in view of the overall appearance of the attendant cloud system.

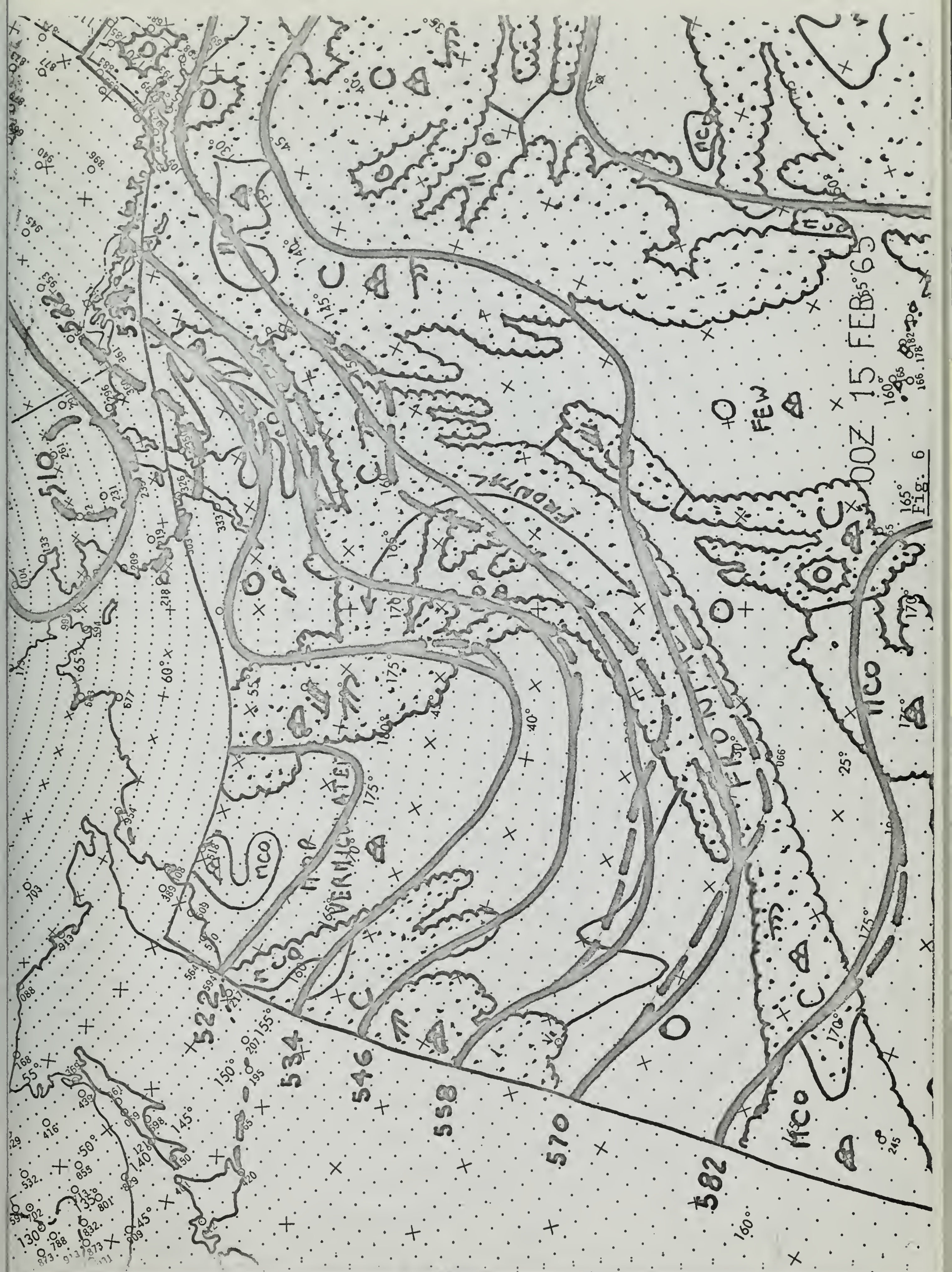
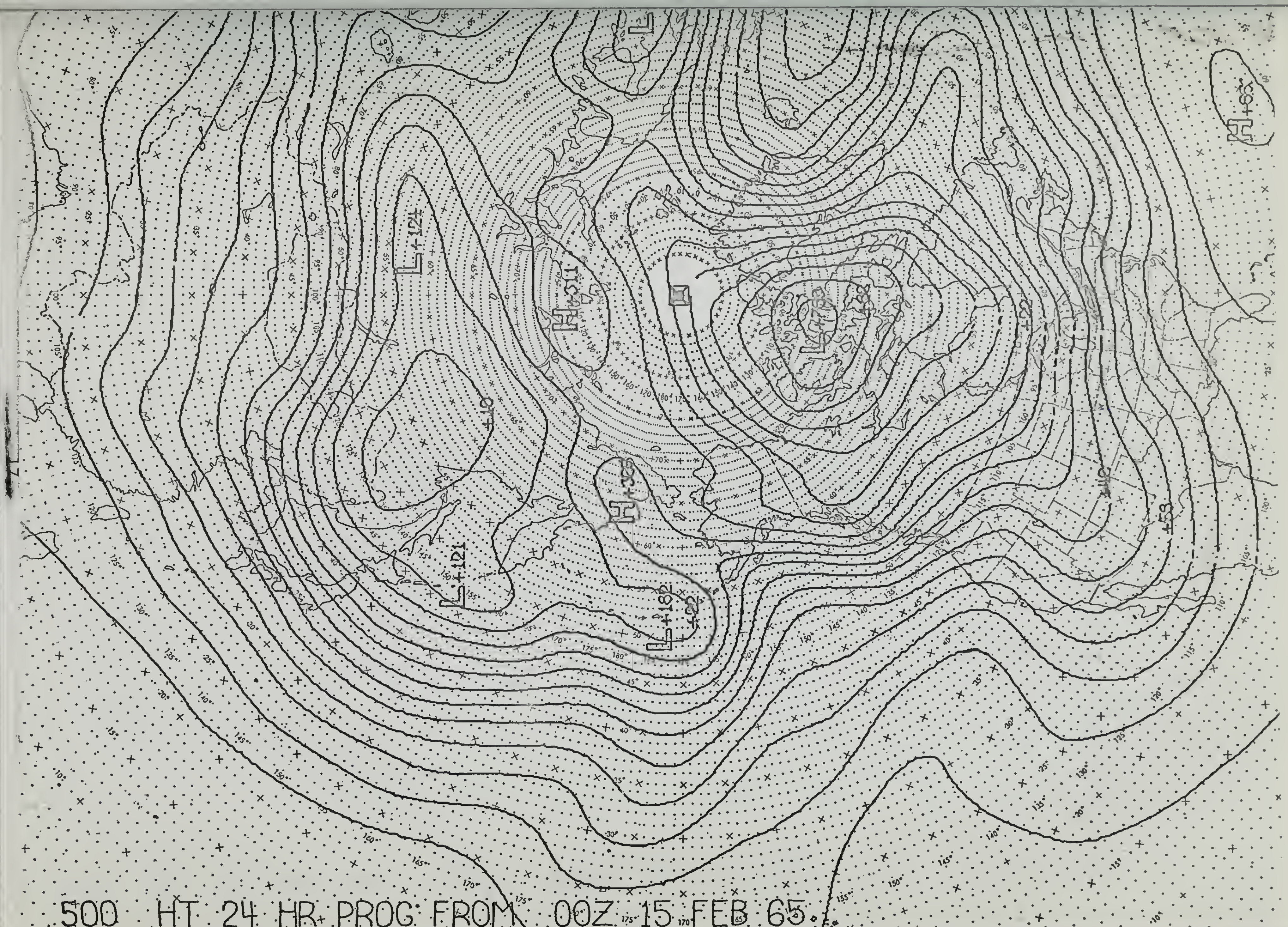


Fig. 6 00Z 15 FEB 65



500 HT 24 HR PROG FROM 00Z 15 FEB 65

Fig. 7

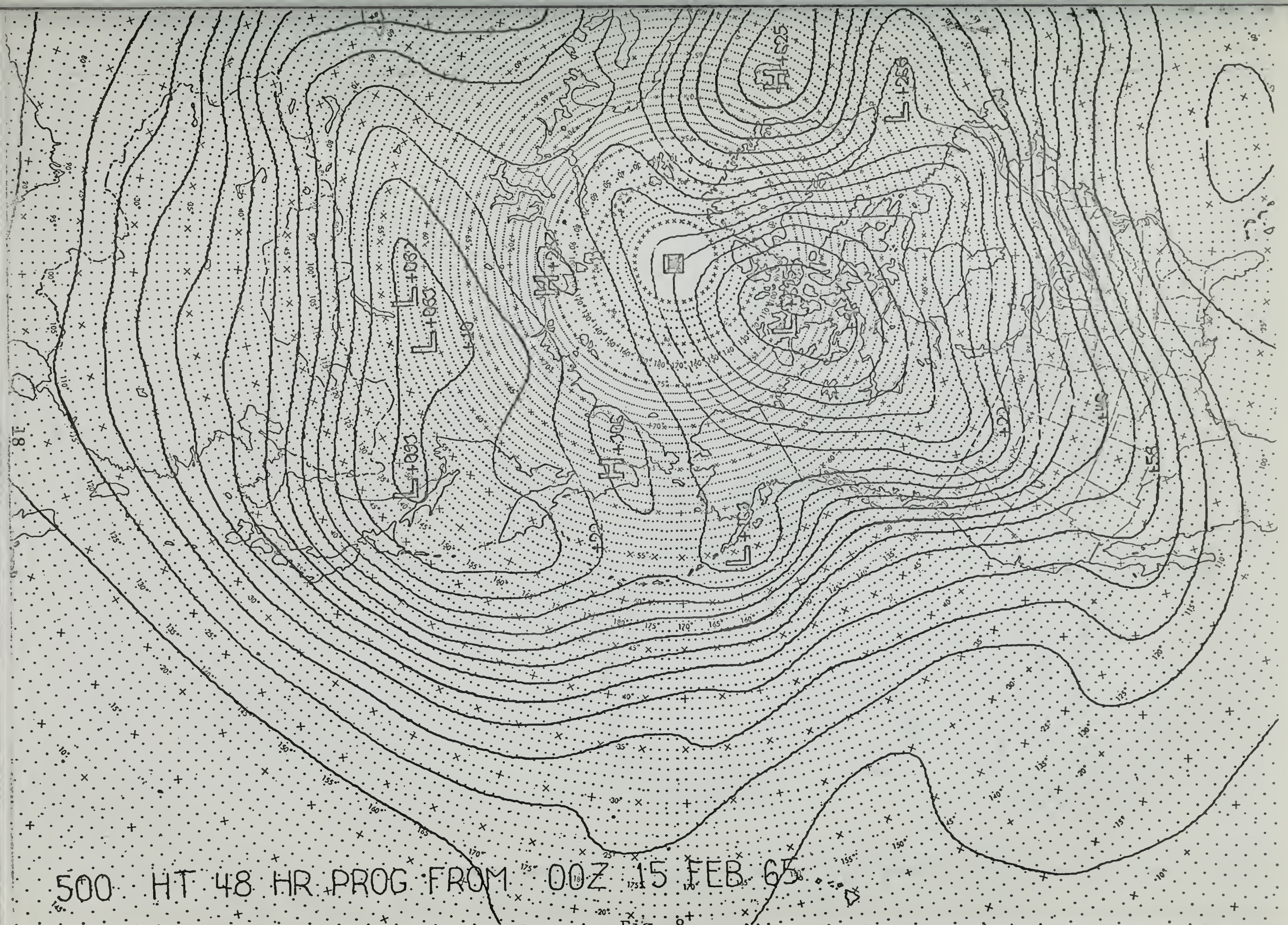
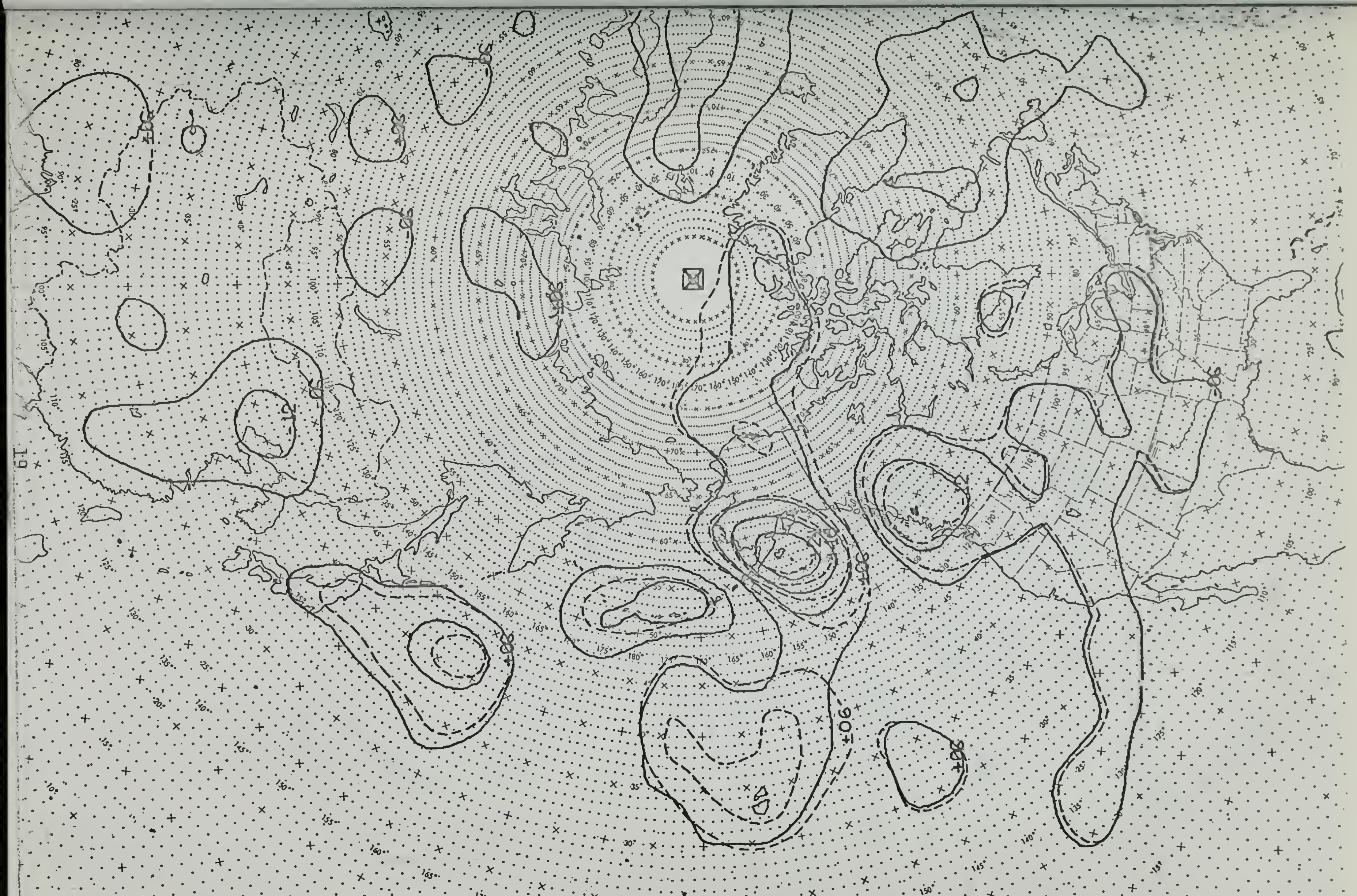
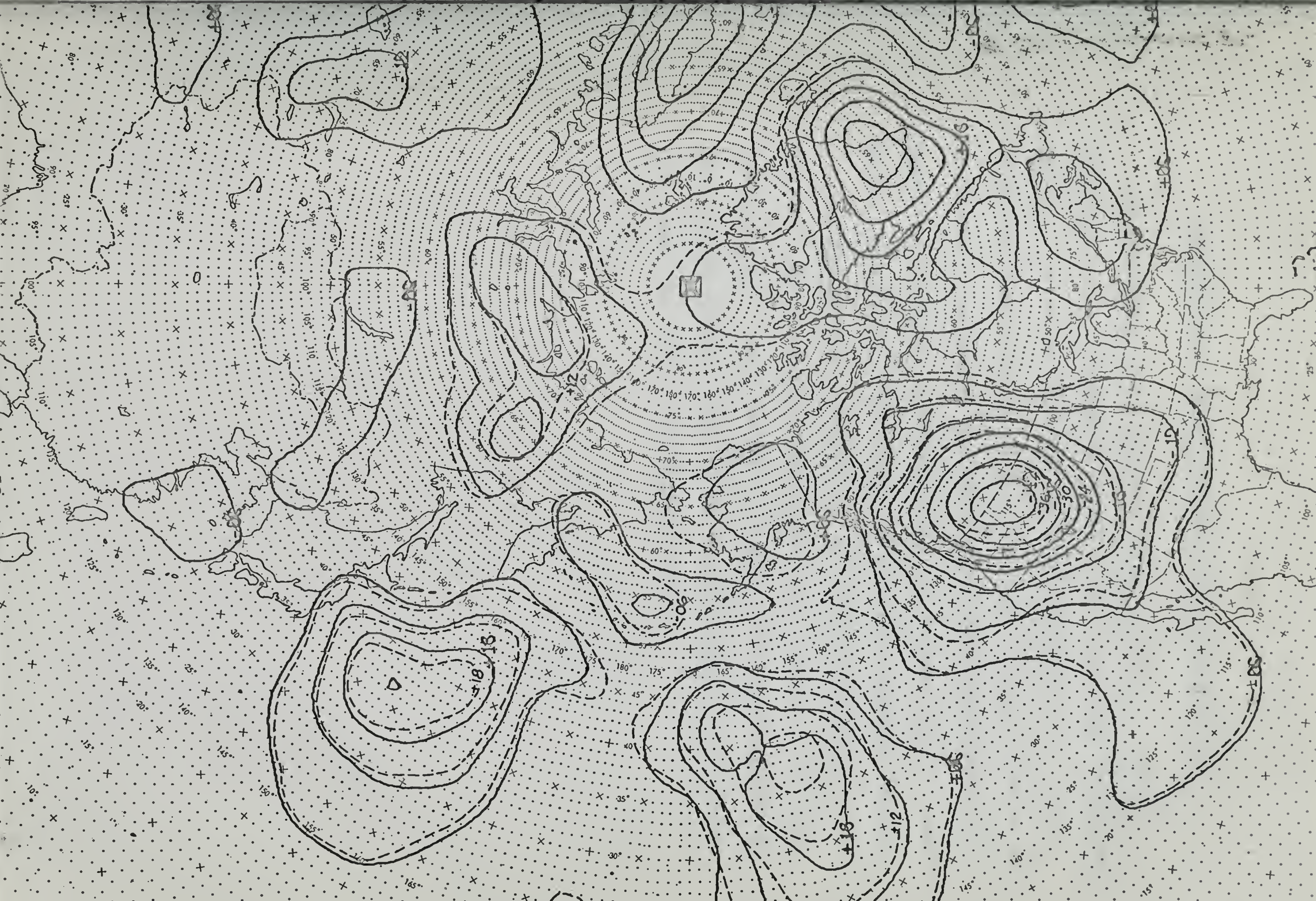


Fig. 8



V 500 24F 24HR 00Z 15 FEB - ANAL 00Z 16 FEB 65

Fig. 9



U 500 48F 48HR 00Z 15 FEB - ANAL 00Z 17 FEB 65

Fig. 10

DISCUSSION OF MODIFICATIONS ON 16 FEBRUARY 1965

As mentioned on the previous day's discussion, a fully-developed vortex now appears at 45N 171W. The trough associated with this vortex was modified and moved eastward so as to lie across the vortex and parallel to the frontal band, crossing the southernmost portion of the frontal band where the synoptically significant portion of the band ends and becomes simply a band of broken cloud cover. The trough has also been slightly deepened.

It must be kept in mind that the Tiros pictures, which are the basis for the nephanalyses, were not all taken at the 00Z synoptic time. The Tiros pictures were taken approximately 1½ hours before synoptic time in the Eastern Pacific and 1½ hours after synoptic time in the Western Pacific.

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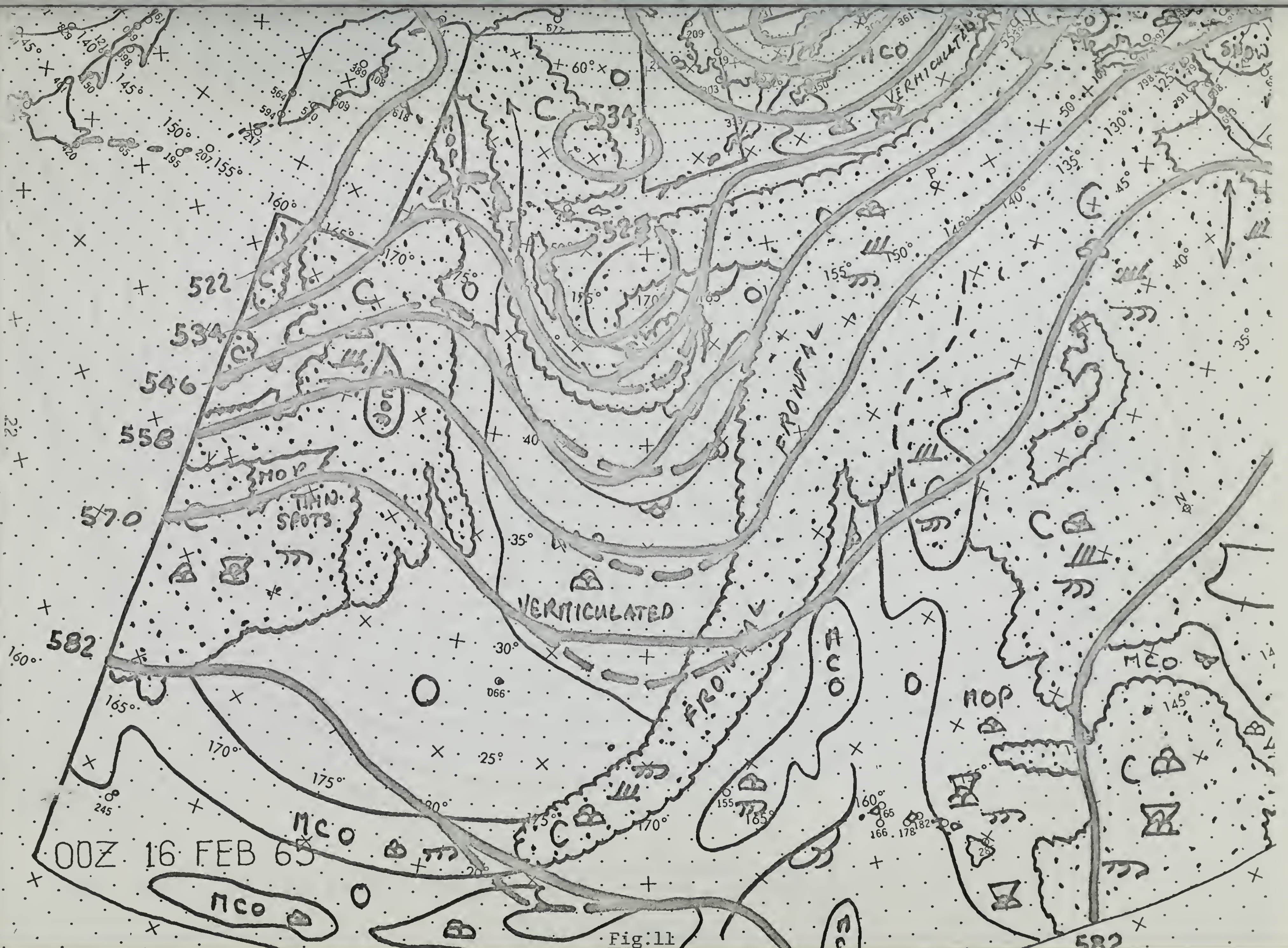

00Z 16 FEB 65
522
534
546
558
570
582
VERMICULATED
FRONTAL
MOP
THIN SPOTS
MCO

Fig.11

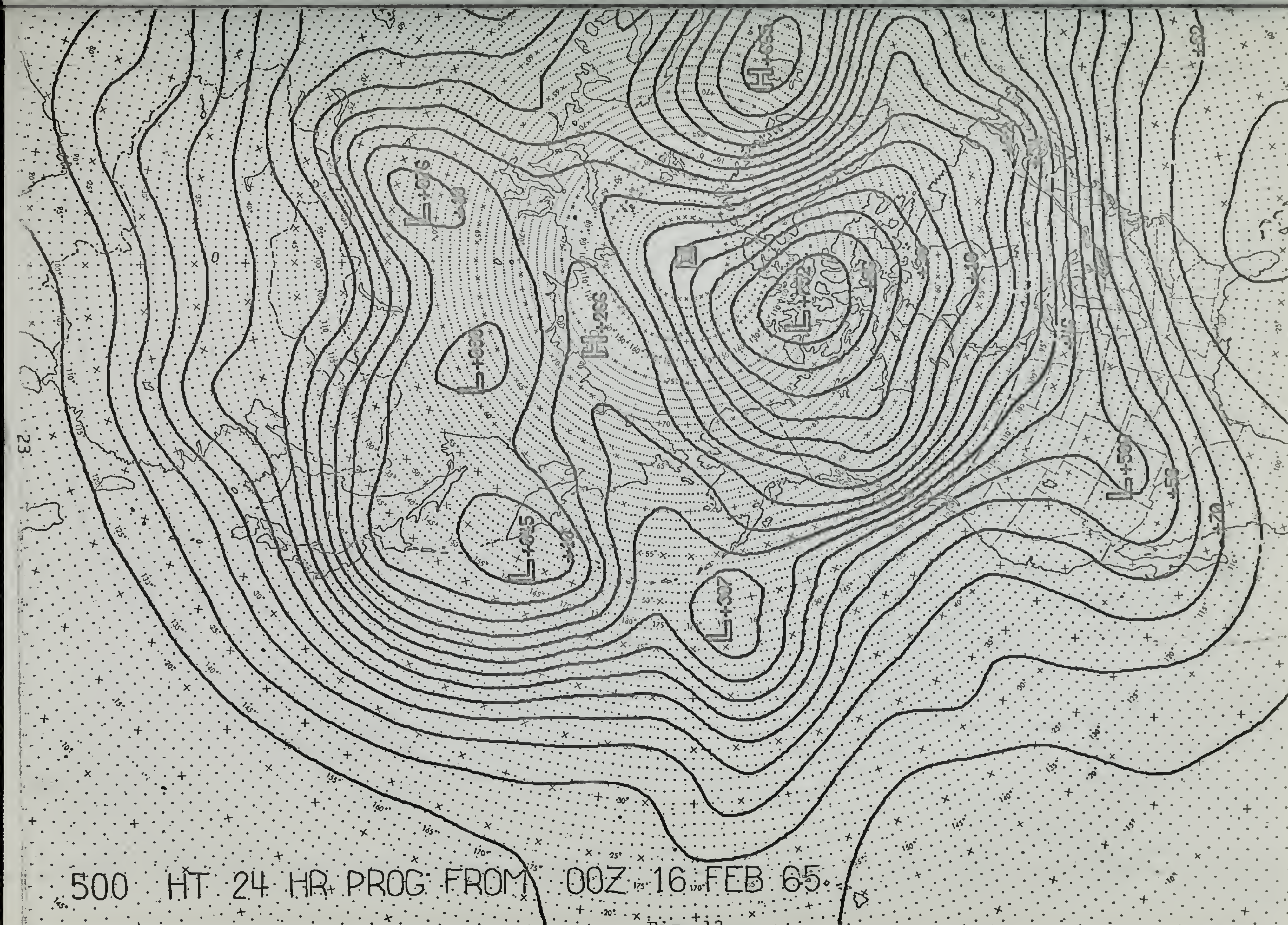
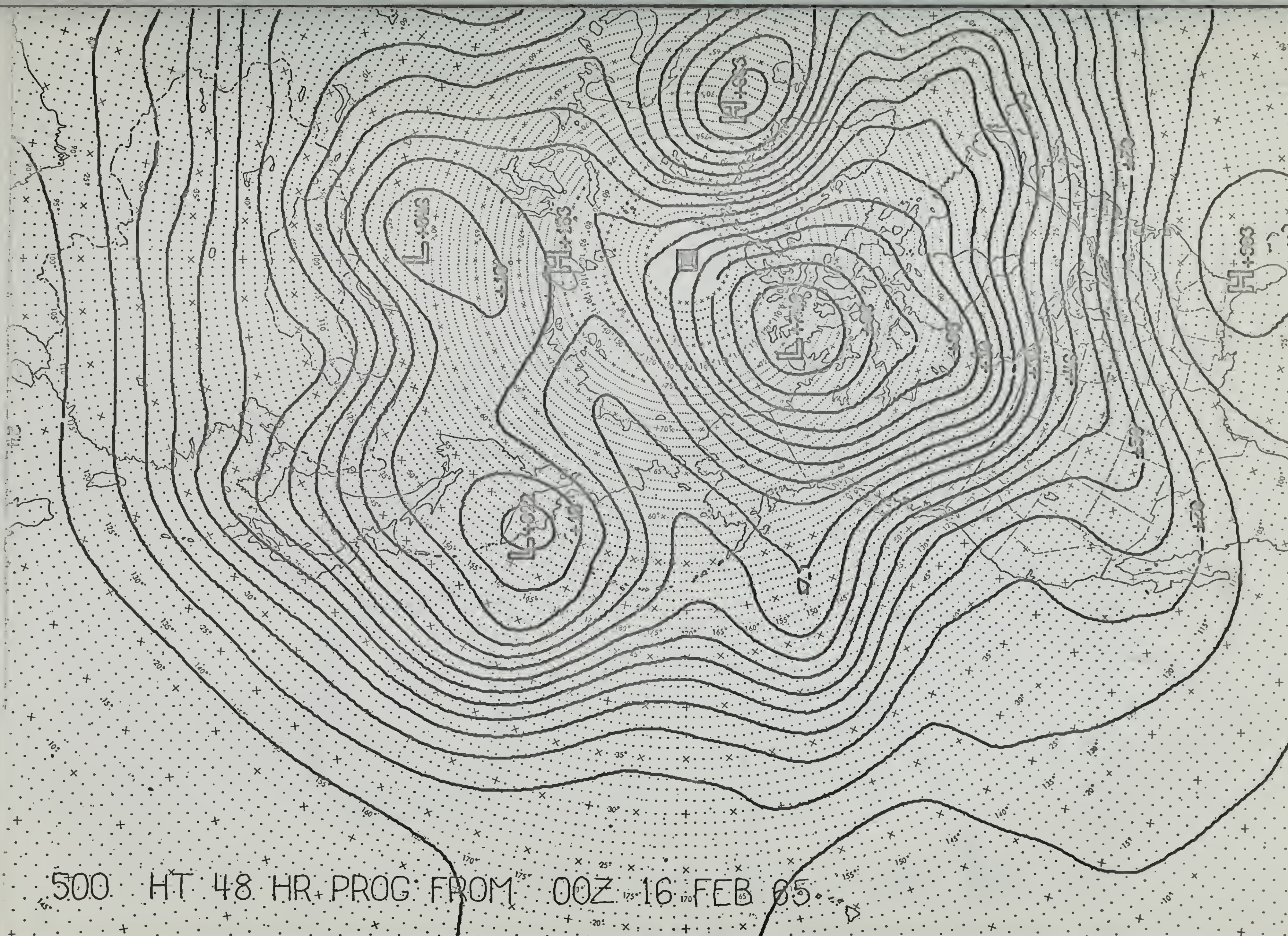
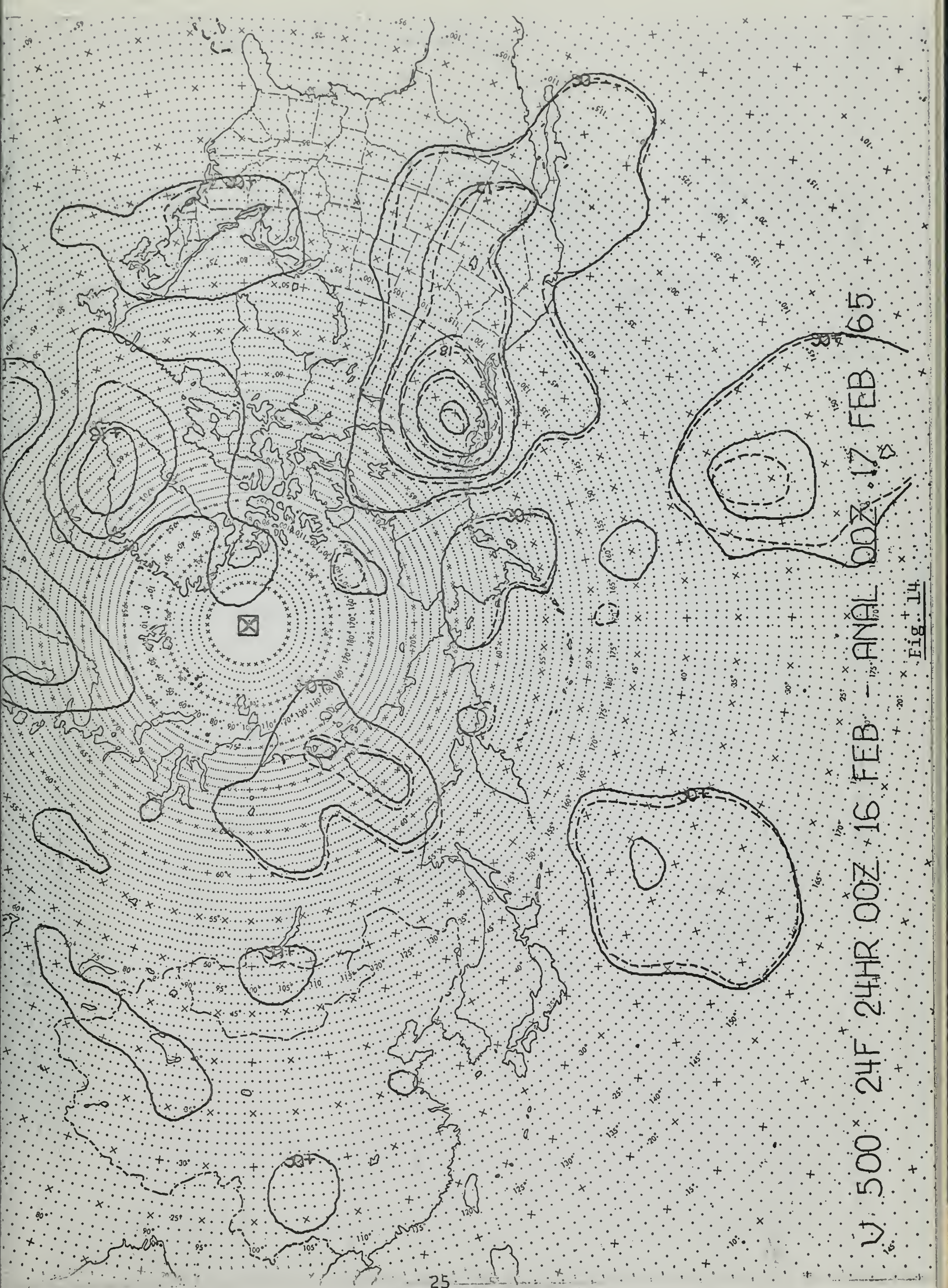


Fig. 12



500 HT 48 HR PROG FROM 00Z 16 FEB 65

Fig. 13



V 500 24F 24HR 00Z 16 FEB - ANAL 00Z 17 FEB 65

Fig. 14

V 500 48F 48HR 00Z 16 FEB - ANAL 00Z 18 FEB 65

Fig. 15

DISCUSSION OF MODIFICATIONS ON 17 FEBRUARY 1965

The vortex at 41N 165W appears to be a cold low. The trough was modified to place it more nearly over the vortex and to parallel the frontal band, crossing where the cloud band becomes less significant. The trough was also extended northward from the vortex, and the ridge to the west of the vortex was amplified to allow the contours to be more nearly parallel to the striations around the vortex.

It was assumed that the eastern portion of the frontal band just north of Hawaii was due to a pre-frontal instability line.

Note the appearance of a vortex, south of the Kamchatka Peninsula, on the northwestern edge of the area of interest.

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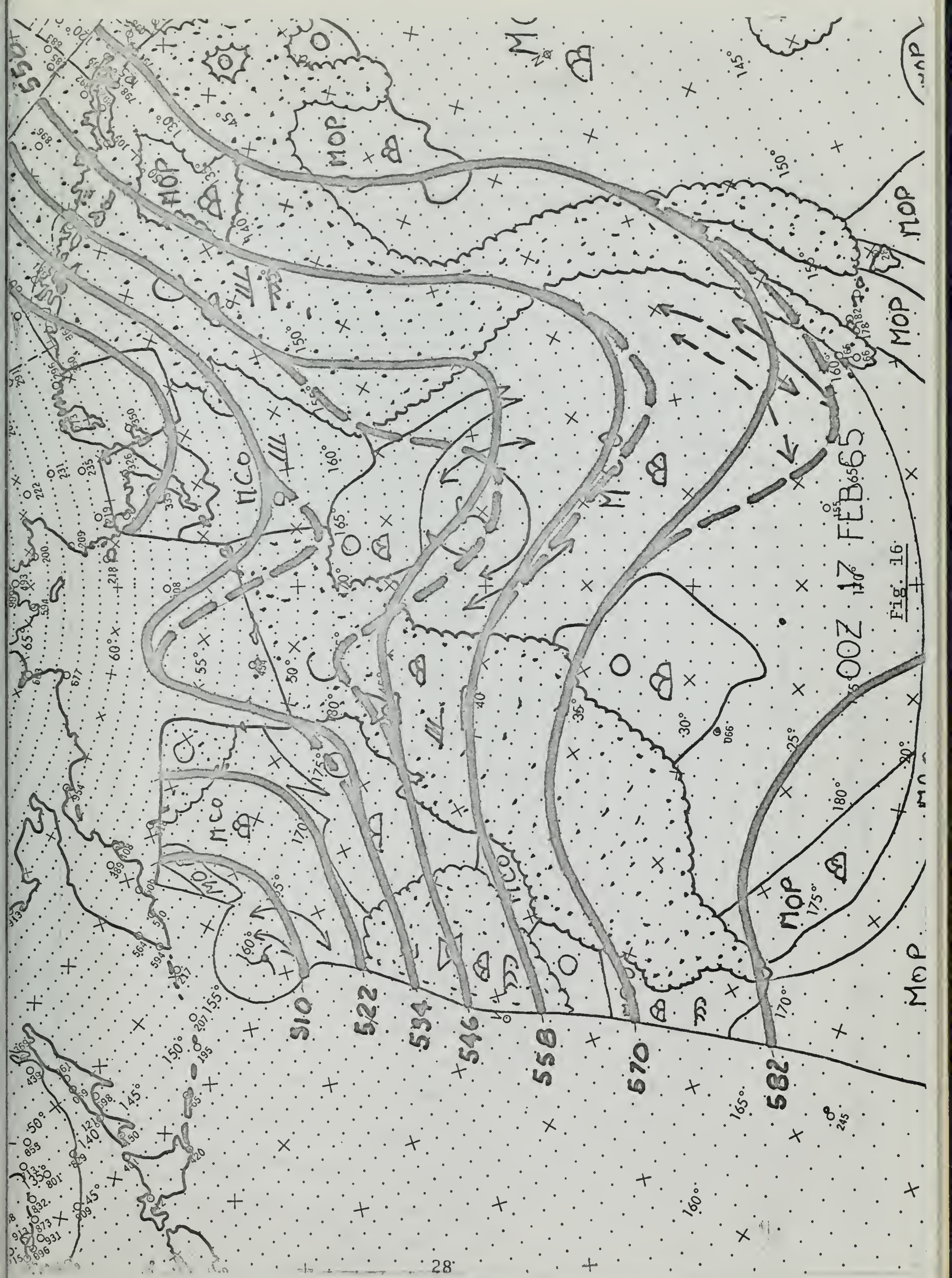
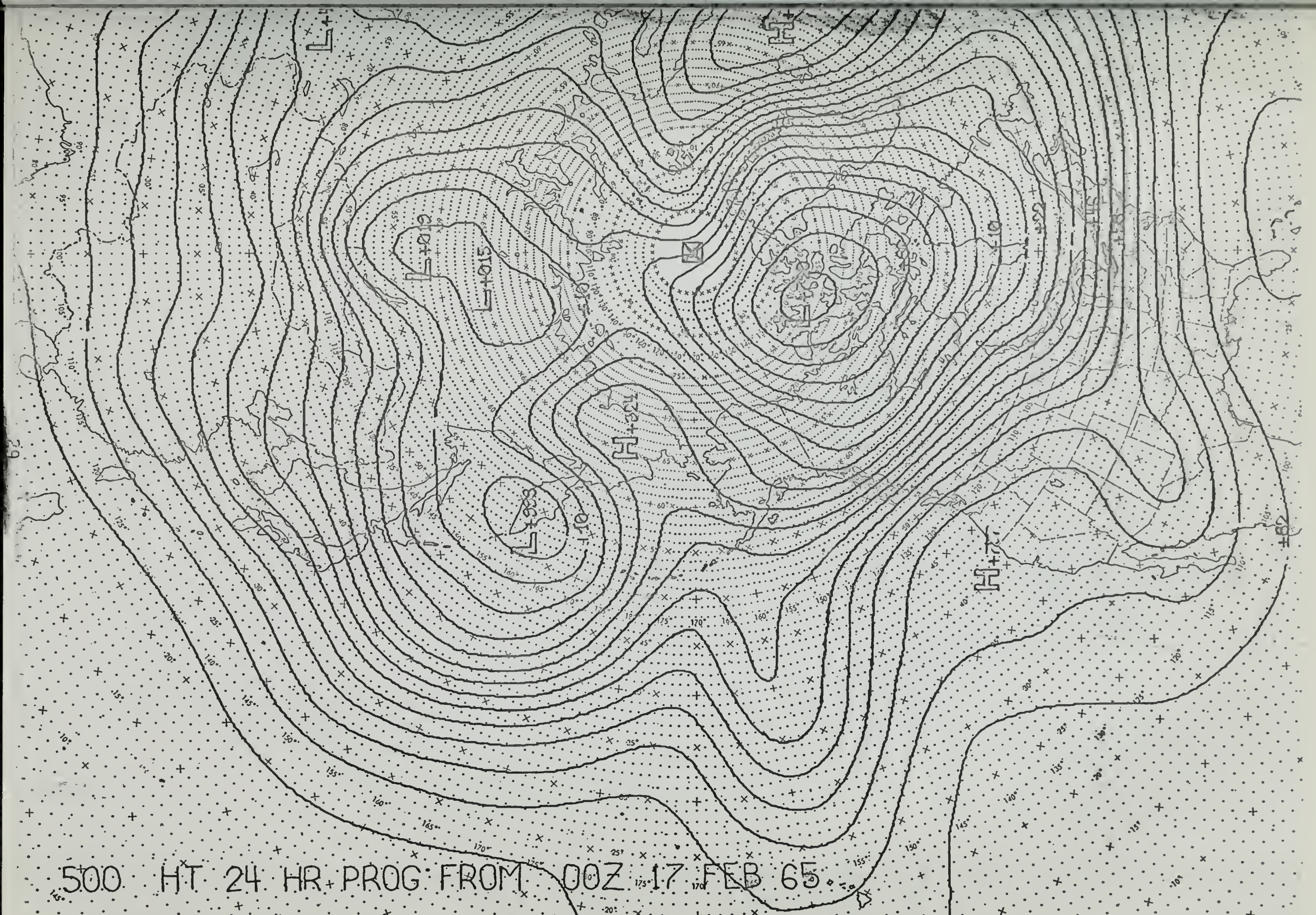
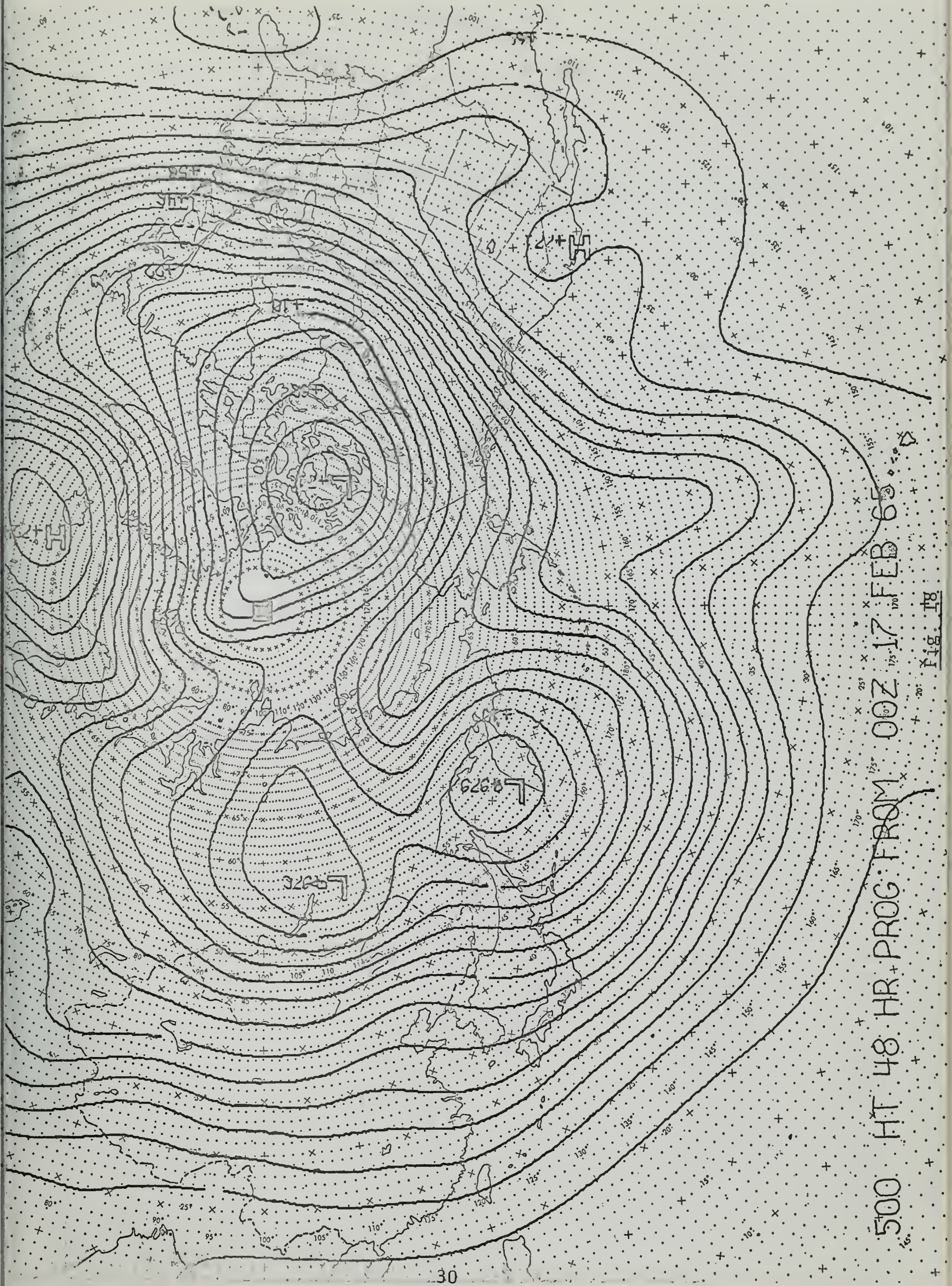


Fig. 16



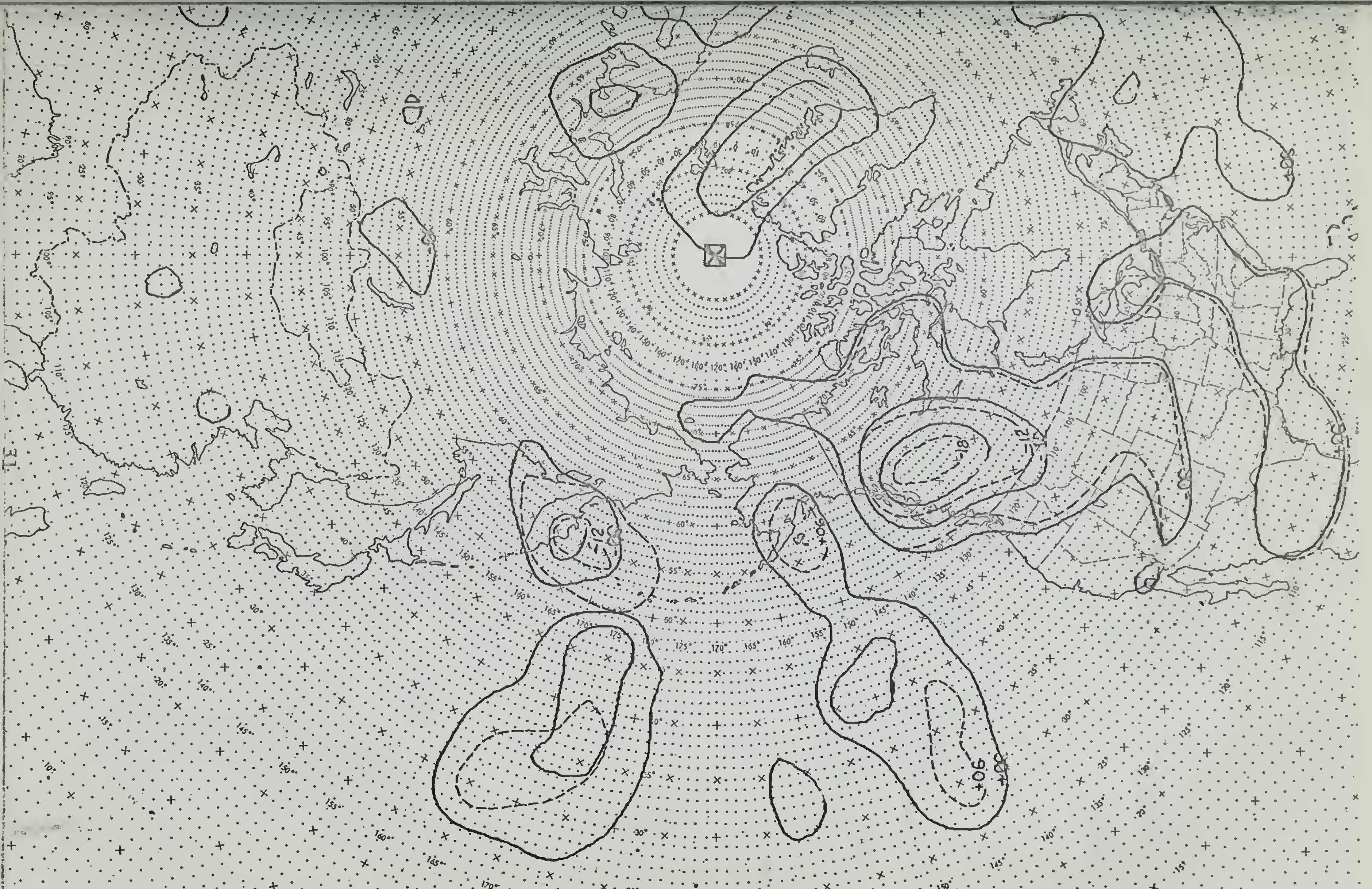
500 HT 24 HR PROG FROM 00Z 17 FEB 65

Fig. 17



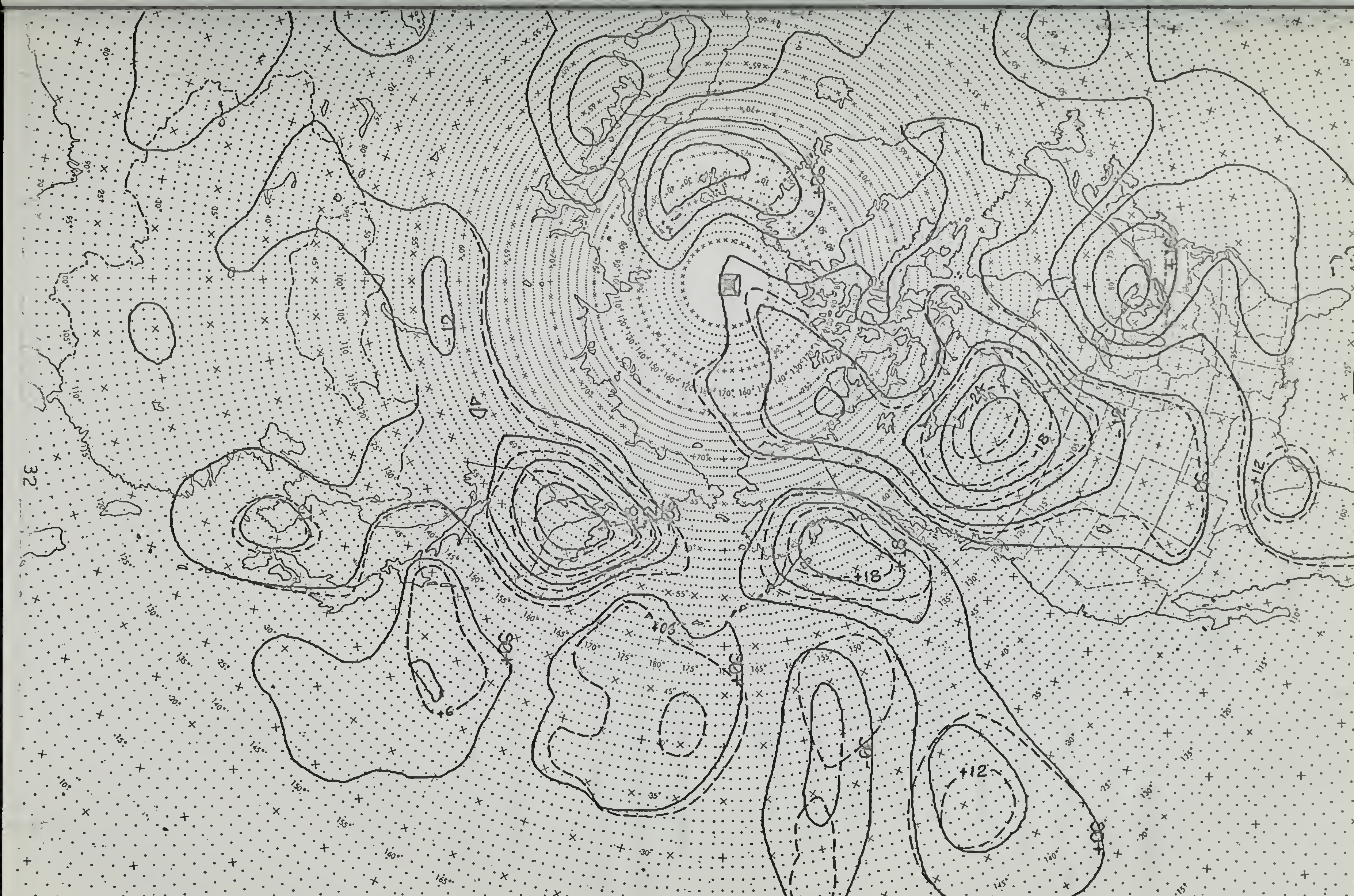
500 HT 48 HR PROG FROM 00Z 17 FEB 65

Fig. 18



V 500 24F 24HR 00Z 17 FEB - ANAL 00Z 18 FEB 65

Fig. 19



V 500 48F 48HR 00Z 17 FEB - ANAL 00Z 19 FEB 65

Fig. 20

DISCUSSION OF MODIFICATIONS ON 18 FEBRUARY 1965

The cold cyclonic vortex south of the Aleutians on 17 February has now disappeared and two new vortices appeared. It may be that a portion of the former moved southeastward, regenerated, and is now a weak vortex in the comma-shaped cloud at 35N 152W. In this case, the vortex north of the comma-shaped cloud represents a remnant of the cold low in the major long-wave trough. In either case, a closed 500-mb low was placed around the northern vortex, and its associated trough deepened southward so as to lie just upwind of the comma-shaped cloud, with the trough trailing to the southwest into the area of broken clouds. This modification also aligned the contours more nearly parallel to the striations.

A closed low was inserted around the vortex located southeast of the Kamchatka Peninsula at the 47N 172E, and the trough associated with this vortex was moved further east and aligned more nearly parallel to the cloud band associated with this vortex.

Since both troughs were deepened slightly and moved closer together, the intervening ridge was flattened slightly in order to decrease the intensity of meridional flow.

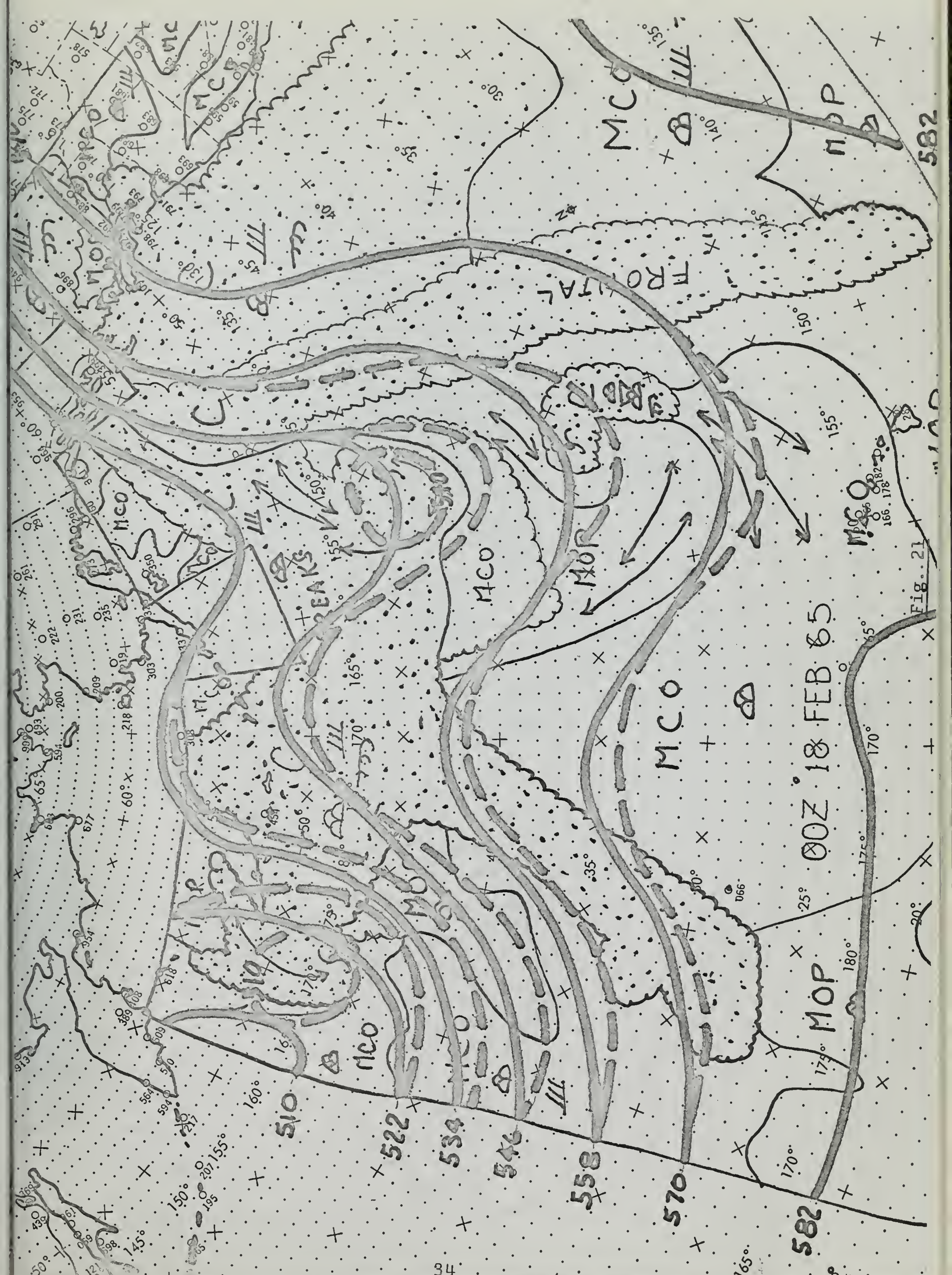
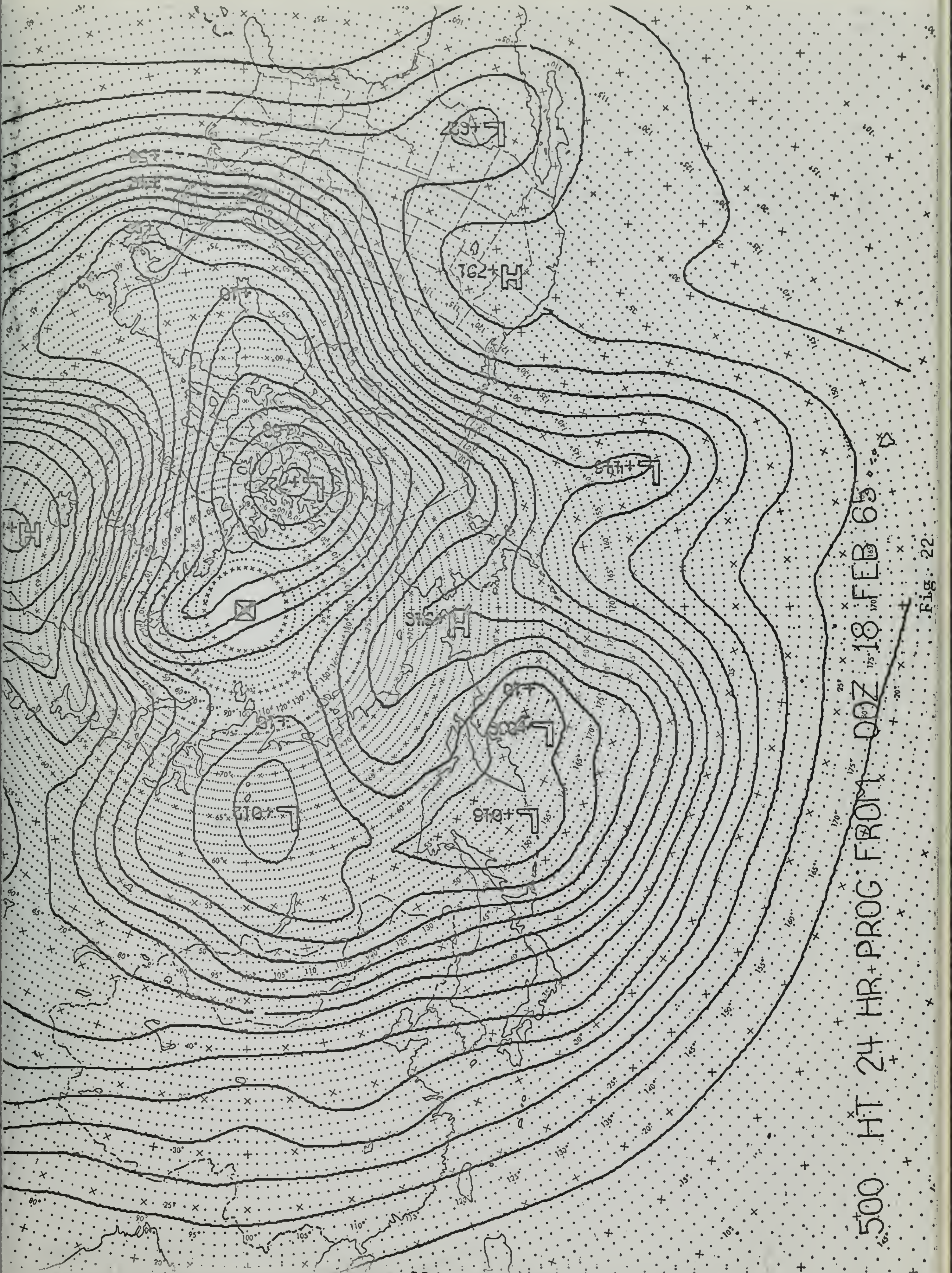
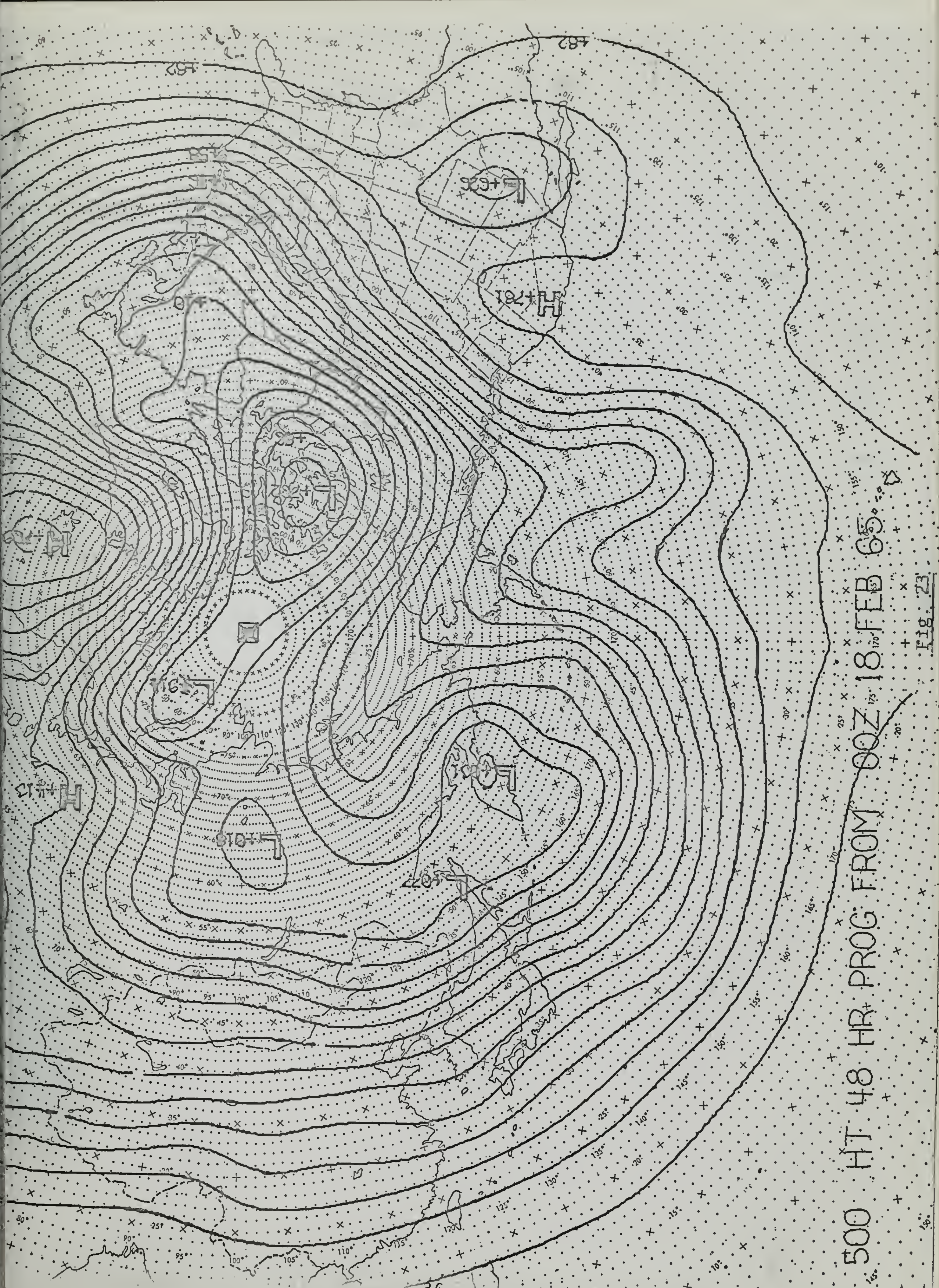


Fig. 21



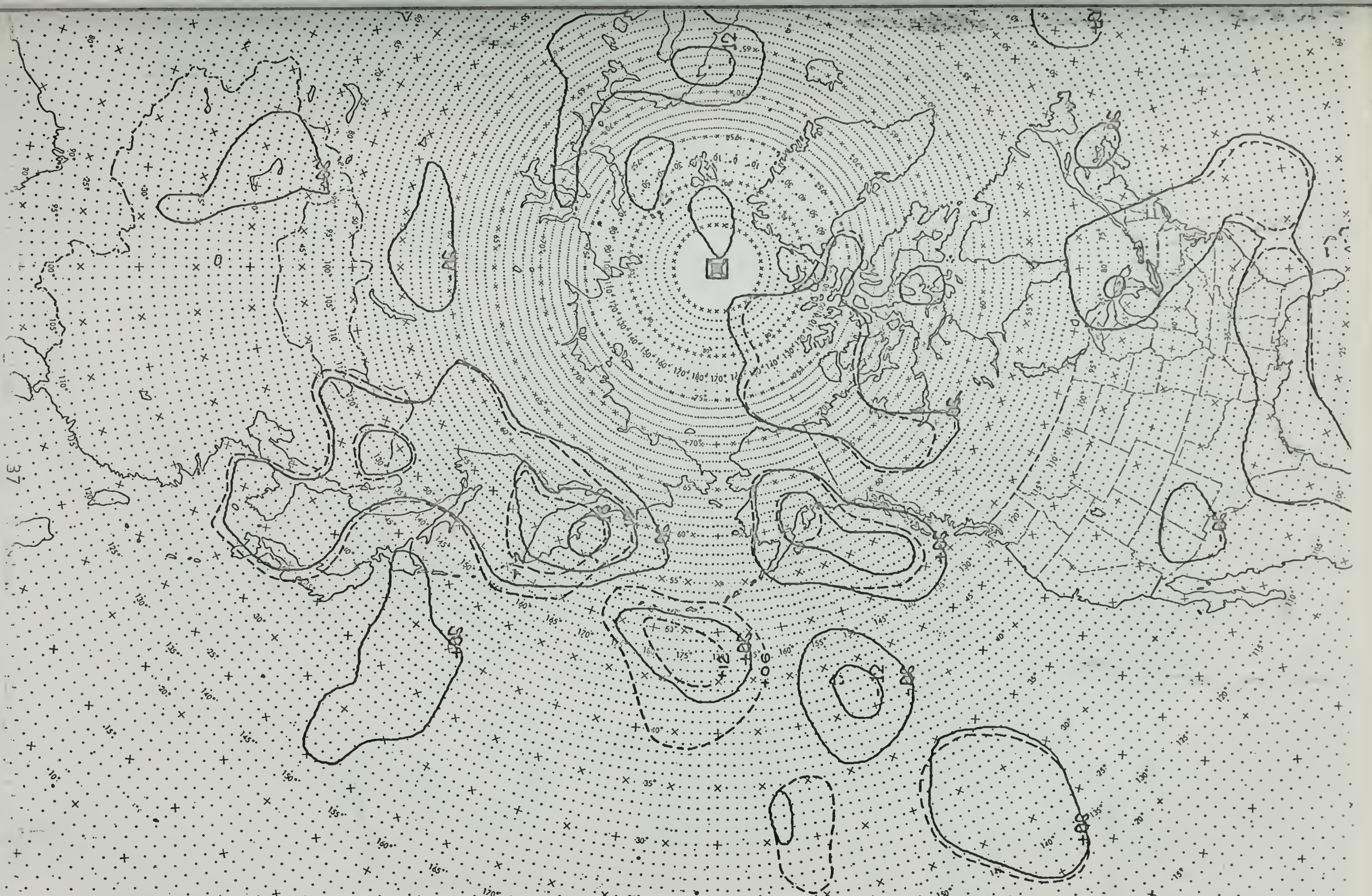
500 HT 24 HR PROG FROM 00Z 18 FEB 65

Fig. 22



500 HT 48 HR PROG FROM 00Z 18 FEB 65

Fig. 23



V 500 24F 24HR 00Z 18 FEB - ANAL 00Z 19 FEB 65

Fig. 24

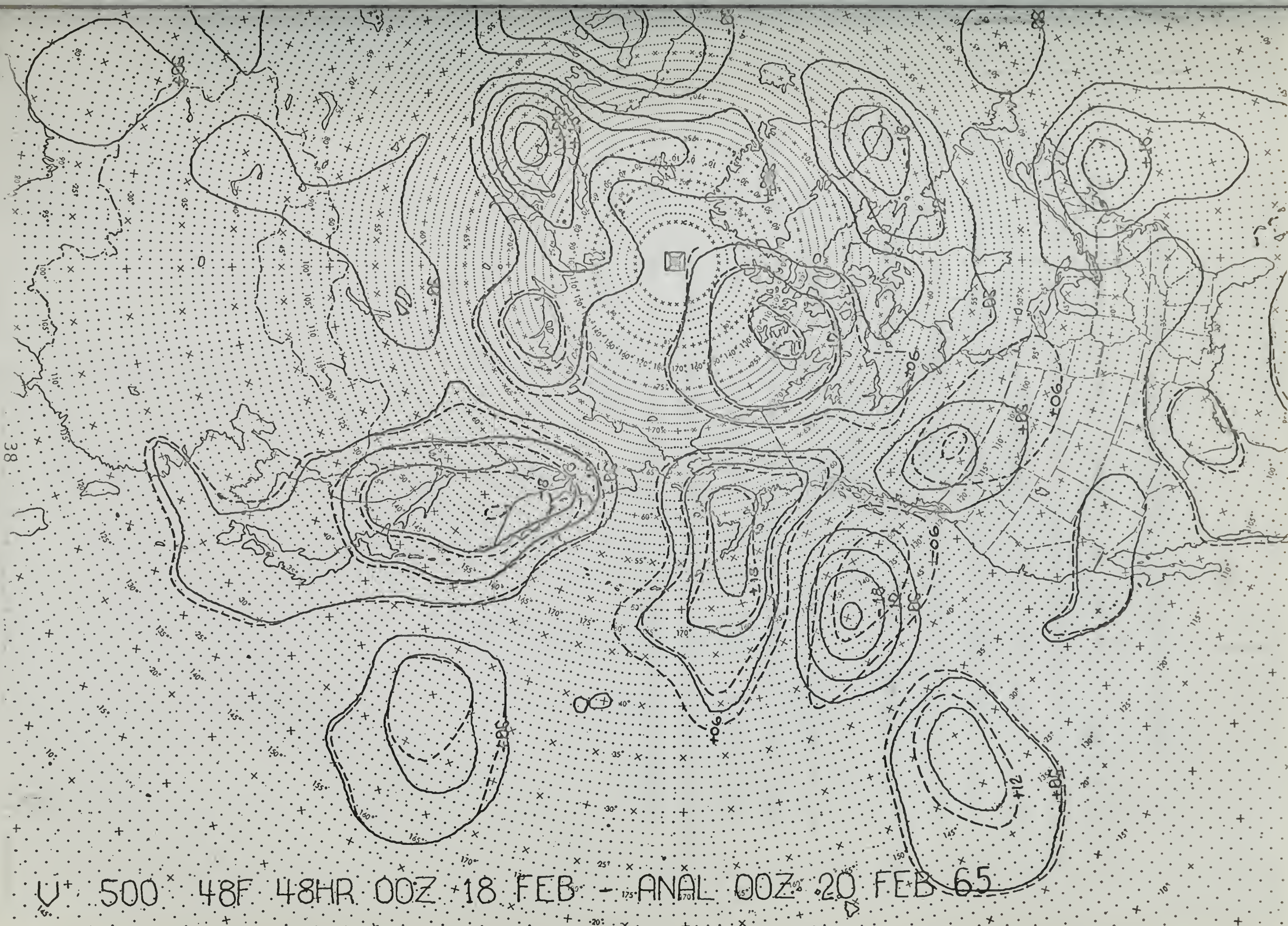


Fig. 25

DISCUSSION OF MODIFICATIONS ON 19 FEBRUARY 1965

The northernmost vortex, formerly in the Gulf of Alaska, has moved out of the picture to the northeast; the cloud mass associated with the weak vortex and comma-shaped cloud of the 18th has attached itself to the larger frontal cloud band (36N 146W) which continues association with the major trough. This vortex was enclosed with a 500-mb low and no change was made in the trough alignment or location, as it appears to fit the cloud patterns well.

FNWF now has a closed low about the probable location of the vortex that was southeast of the Kamchatka Peninsula on the 18th, but which is not in the nephanalysis of this date. A short-wave trough was extended from the low through the weak circulation center (near 40N 150E) crossing the frontal band where the band becomes narrow and zonally oriented.

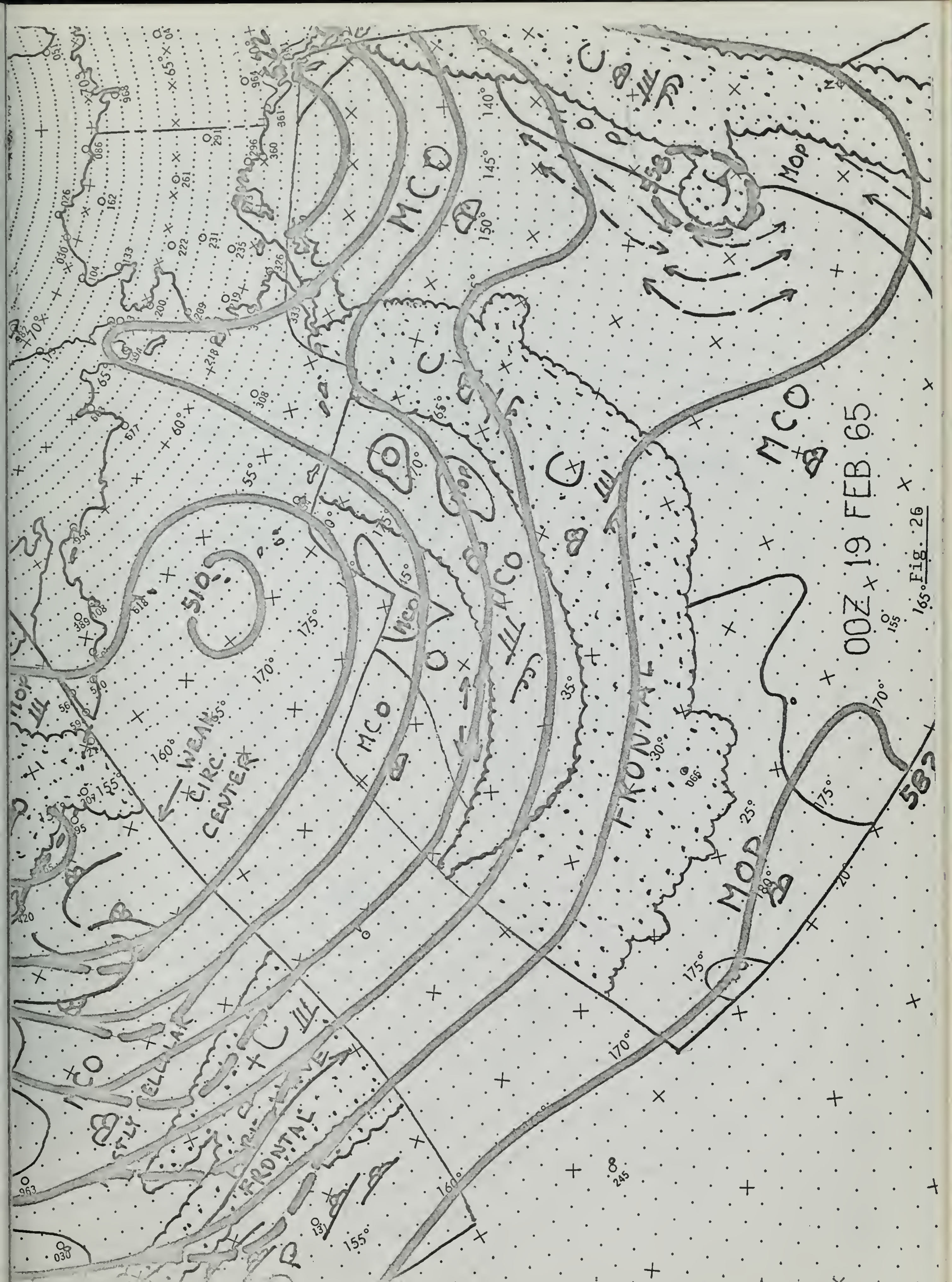
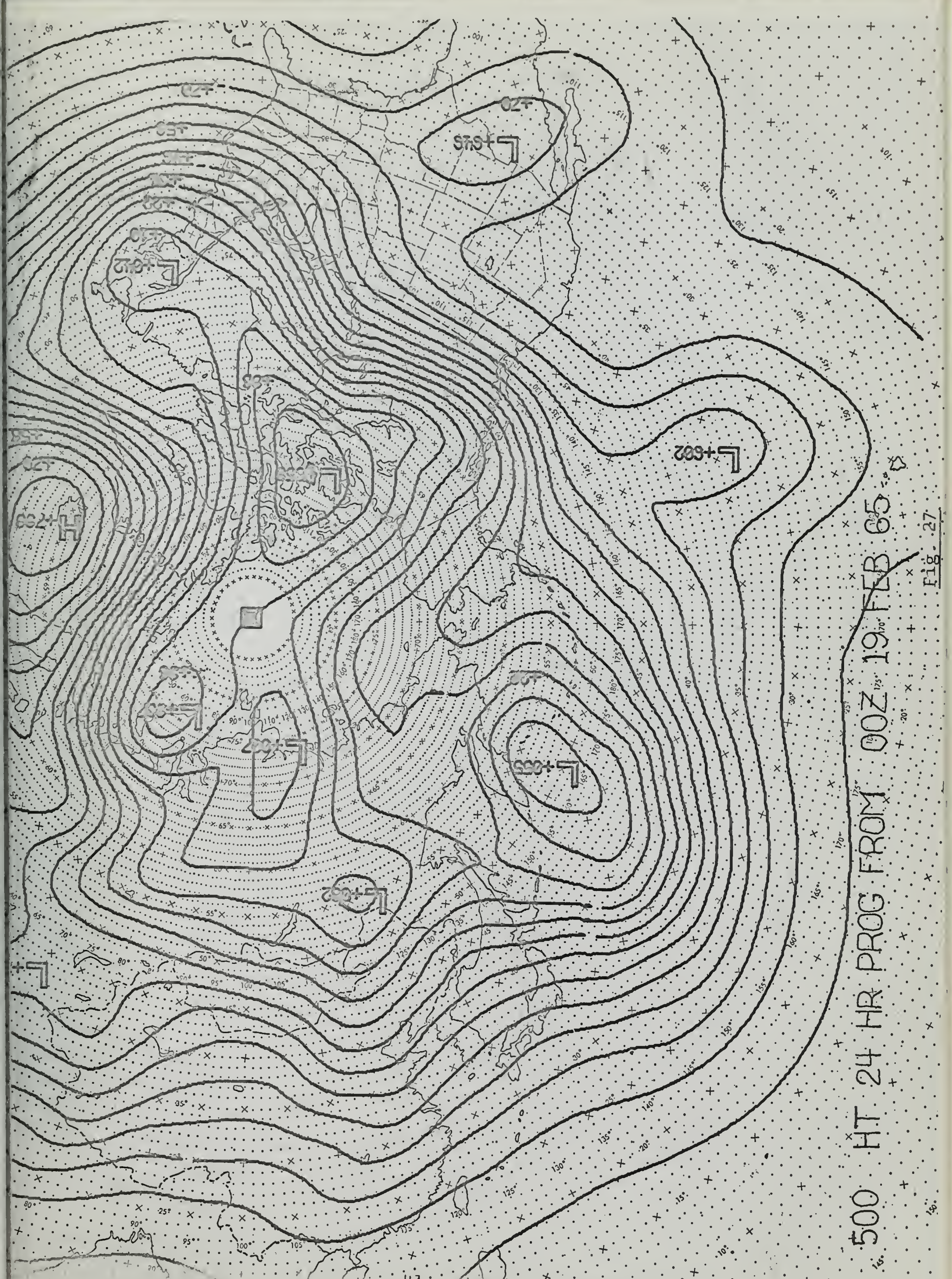


Fig. 26



500 HT 24 HR PROG FROM 00Z 19 FEB 65

Fig. 27

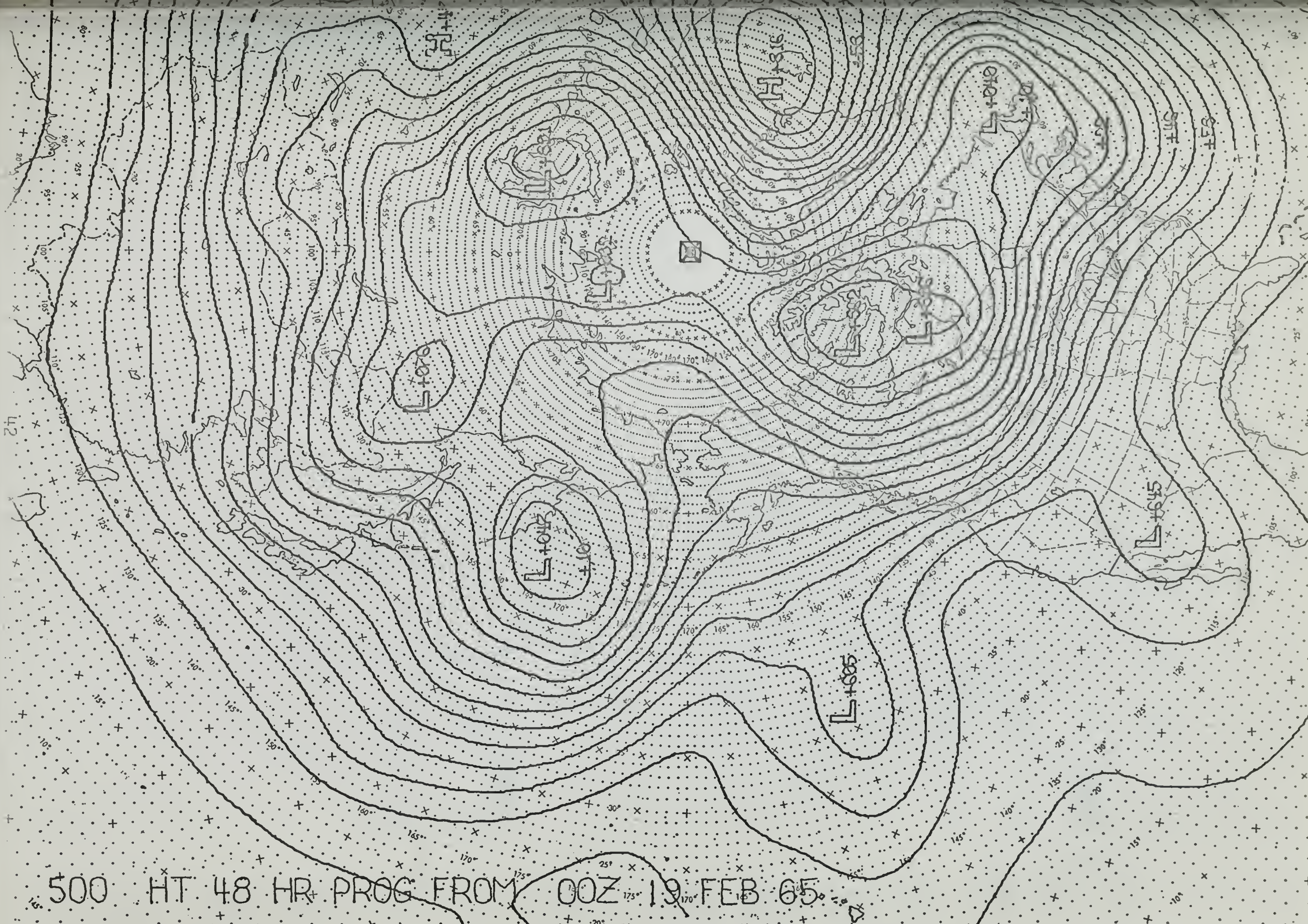
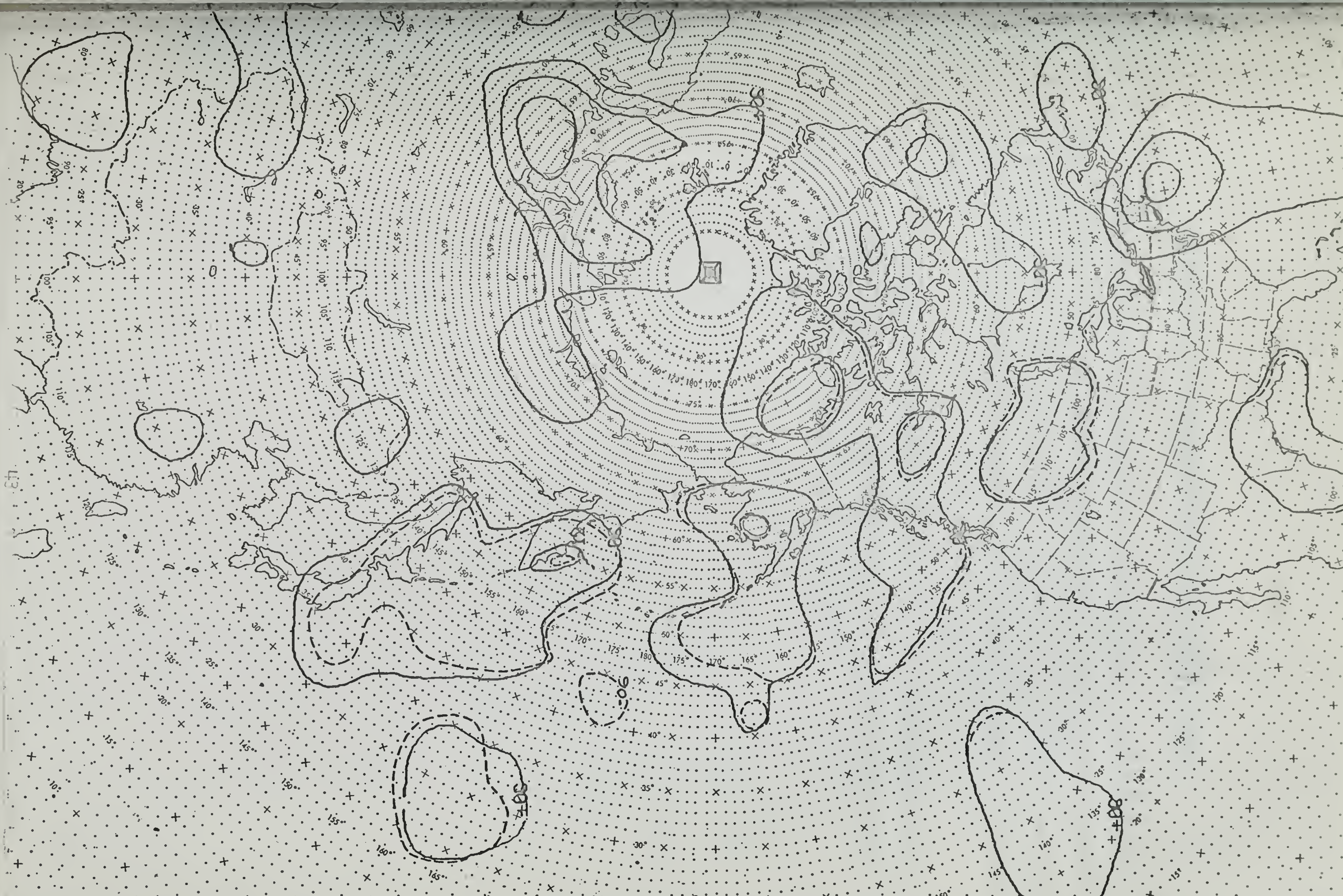


Fig. 28



V 500 24F 24HR 00Z 19 FEB - ANAL 00Z 20 FEB 65

Fig. 29

DISCUSSION OF MODIFICATIONS ON 20 FEBRUARY 1965

The vortex which was located at 36N 146W on 19 February 1965 does not appear in the current nephanalysis, but FNWF has analyzed a low near its previous location. The low was enlarged to contain the area where the vortex would be if it were not masked by higher clouds.

A new vortex has appeared to the east of the southern tip of the Kamchatka Peninsula. The trough associated with this vortex was deepened slightly and moved to the east.

Fig. 30

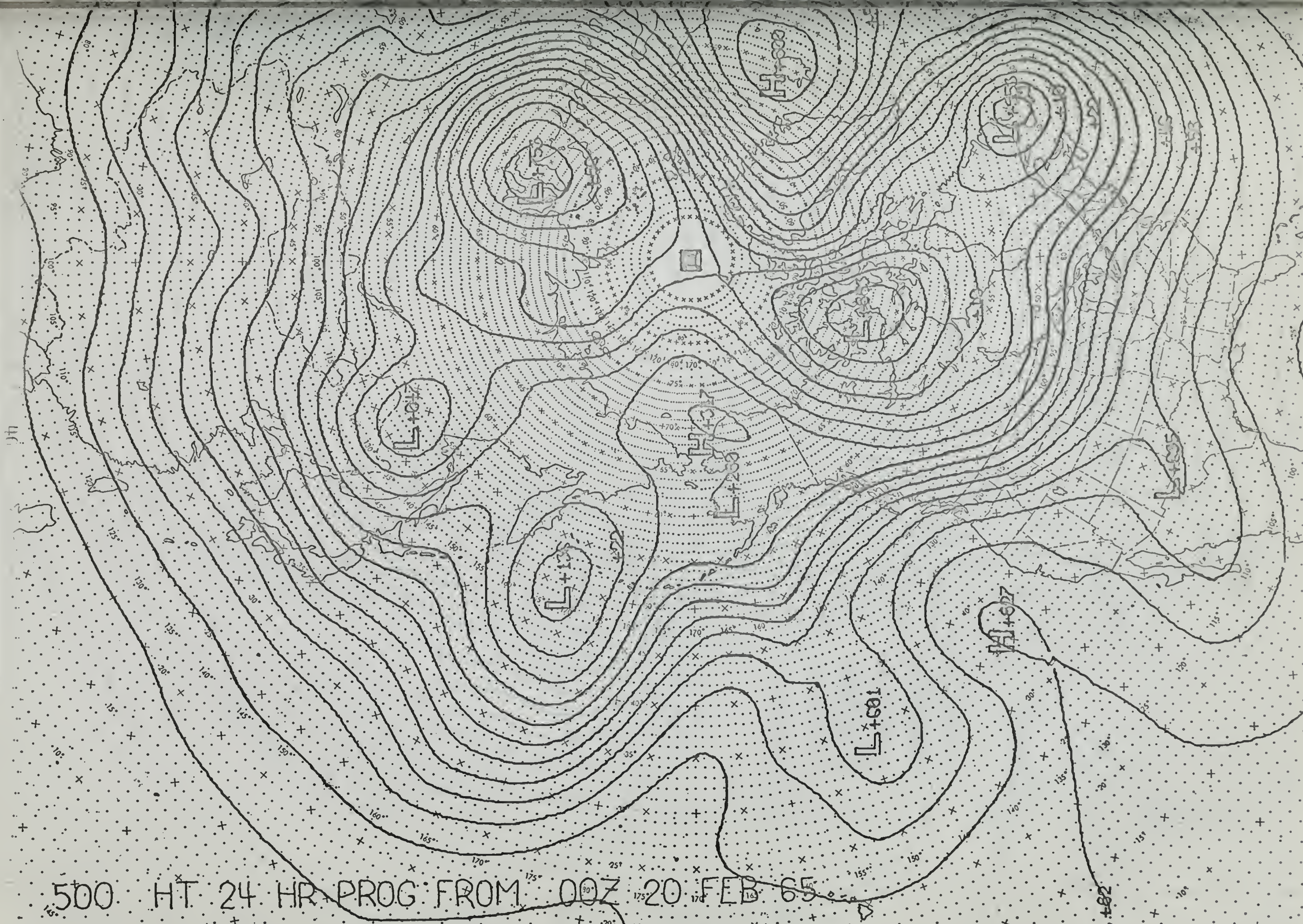


Fig. 31

500 HT 48 HR PROG FROM 00Z 20 FEB 65

Fig. 32

SECTION VI

Results

The results of this experiment are clearly displayed in the maps of prognostic verifications (figures 4, 5, 9, 10, 14, 15, 19, 20, 24, 25, 29) and in Table 1. From Table 1, it is readily evident that improvement in 24-hour prognoses was made only through modification of the 14 February contour analysis. On other days the modified prognoses fared worse than the original prognostic products.

In looking through the maps of prognostic verification, several items stand out. The remarkable similarity of algebraic signs in the original and modified difference patterns is immediately noticeable. Rarely does a conflict in signs arise. That is, seldom does the modified difference field have a negative difference value at a position where the unmodified field has a positive difference value, or vice versa.

Most of the pattern displacements between the modified and the original difference patterns take place, as expected, near the areas in which the modifications were made. Although the RMSE values for the 15th February through the 19th February show larger values for the modified than for the original products, there are some areas in which the modified difference fields are less than those of the original fields and other areas where the reverse is true. This is not shown in Table 1 since the RMSE accounts for the whole North Pacific Ocean or a large segment of the North Pacific from 130W westward to 135E. On inspection, it does not appear that the areas of improvement (i.e. improved verification) or areas of increased differences

(i.e. worsened verification) are solely confined to the local area of modification, but that there is some "spreading out" of the effects of reanalysis, especially to the east and north beyond the area of modification. This "spreading out" effect is logically a result of the particular FNWF Barotropic Model used in calculating the prognoses.

More extensive and somewhat different experiments have been conducted by the USWB involving modification of fields of vorticity and vorticity advection. The reader is referred to [9] [10] for details.

TABLE 1

TIME-DATE[1]	Area[2,3]	24-Hour Prog. From[1]	MINUS Analysis of[1]	24-Hour RMSE (in feet) Modified	24-Hour RMSE (in feet) Original	48-Hr. Prog. From[1]	MINUS Analysis of	48-hr RMSE (in ft.) MOD.	48-hr RMSE (in ft.) Original
14	N.Pacific	14	15	94.4	96.7	14	16	171.2	UNAVAILABLE
	130W to 135E	14	15	105.8	107.5	14	16	195.3	UNAVAILABLE
15	N.Pacific	15	16	124.1	117.9	15	17	188.5	UNAVAILABLE
	130W to 135E	15	16	147.2	142.5	15	17	214.6	UNAVAILABLE
16	N.Pacific	16	17	125.5	116.8	16	18	171.6	UNAVAILABLE
	130W to 135E	16	17	144.1	135.2	16	18	199.8	UNAVAILABLE
17	N.Pacific	17	18	106.4	73.0	17	19	141.4	UNAVAILABLE
	130W to 135E	17	18	133.8	97.2	17	19	195.1	UNAVAILABLE
18	N.Pacific	18	19	98.8	92.4	18	20	155.0	UNAVAILABLE
	130W to 135E	18	19	131.9	121.0	18	20	209.1	UNAVAILABLE
19	N.Pacific	19	20	100.5	90.6				
	130W to 135E	19	20	131.7	120.0				

(1) All times for 00Z, all dates for February 1965
(2) N.Pacific encompasses the entire North Pacific Ocean north of the equator
(3) 130W to 135E encompasses an area from the equator to the North Pole.

SECTION VII

Conclusions

Quite naturally, as must be evident to the readers, the results of this study must be interpreted in light of the dual hypotheses underlying this project, (see introduction). The following qualifications and remarks are pertinent to this interpretation.

Only in the case of 00Z 14 February did the authors have time to remodify the analysis based on the Tiros IX nephanalysis and much increased experience. As noted, analysis of this date led to the best relative verification. The other days very likely suffered from inexperienced, single-attempt modifications and it is manifestly clear to these authors that time allowing, justifiable improvements would be made. It is to be noted that the U. S. Naval Postgraduate School, Monterey, California, introduced satellite cloud-photograph interpretation into the academic program just this year. The authors received this training too late to be effective in the thesis experiment. Also, non-use of the surface analyses evidently led to overemphasis of the association of cloud data with 500-mb flow patterns, as after-the-fact investigations showed. Closely related is the fact that the 24-hour interval between Tiros nephanalyses was too large to permit accurate tracking of vortices, etc., especially without reference to surface data.

It is to be noted that even if one starts with a perfect analysis, baroclinic developments (and there are many of them in the test period) cannot be perfectly forecasted by a barotropic model. Said in another way, a perfect prognosis could only result from an inaccurate analysis.

[illegible]

Unquestionably analysis modification for the period 15-20 February should be redone, perhaps many times, and surface patterns should be taken into account. Each day should be concentrated on individually, and in context with preceding and following days. In attempting modifications for each day, the modifications should be varied considerably to show the effects of their variance. It would indeed be an interesting experiment to have several experts in the field of cloud-photograph interpretation <u>independently</u> modify the analyses from which modified prognoses would be calculated.

SECTION VIII

Acknowledgments

The writers wish to express their appreciation to Associate Professor Robert J. Renard and Commander Norman M. Stevenson of the U. S. Naval Postgraduate School for their guidance and assistance in this study. Appreciation is also expressed to the personnel of the U. S. Navy Fleet Numerical Weather Facility for their cooperation in furnishing data, programs and technical assistance, and also to U. S. Navy Project FAMOS for nephanalyses, photographs and guidance.

SECTION IX

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APPENDIX I

NEPHANALYSIS LEGEND

1. CLOUD TYPES

	Cumuliform		Cirriform
	Apparent CUCG or CB		Stratiform

2. CLOUD AMOUNT (COVERAGE)

O	Open	20%
MOP	Mostly Open	20% - 50%
MCO	Mostly Covered	50% - 80%
C	Covered	80%

3. SIZE OF FEATURES

Cloud	Size (Nautical Miles)	Open Spaces
1	0 - 30	6
2	30 - 60	7
3	60 - 90	8
4	90 - 120	9

4. BOUNDARIES

	Major cloud system		Definite
	Limit of snow or ice		Indefinite

5. PATTERNS AND SYNOPTIC INTERPRETATIONS


Point toward which cloud band(s) tend to spiral


Point in a generally open field of cumuliform clouds toward which cloud elements tend to spiral


Distinct comma shaped cloud mass


Cloud line (form may be )


Cloud line, tenuous

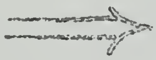

Change of element size along cloud line as indicated


Striations


Striations, tenuous


Wave clouds (mountain or transverse)


Estimated location of the jet


Direction of streakiness in cirrus clouds


Bright (heavy reflective cloud mass)

Thin

6. TERMS

Cellular	-	Pattern of cumuliform cloud elements which form polygons with either open or closed centers
Eddy	-	Mesoscale spiral cloud
Hazy	-	Condition when known terrain features are not seen with usual clarity
Probable	-	Used when only part of cloud system or pattern is visible in satellite picture and there is a high degree of confidence in the interpretation
Possible	-	Used when observed cloud pattern is not a clear-cut example of its type or when other available synoptic data and analysis does not clearly support interpretation

D. Definitions of Associated Terminology

Scale

(a) Large Scale: 2°x2° (latitude) or greater.
(b) Small Scale: Less than 2°x2° (latitude).

Mass

A large-scale area of reflection from clouds, with covered, "C", conditions.

Element

A small-scale area of reflection from clouds.

NOTE: With the suspected resolution of 1-1/2 miles near the principal point decreasing to 5 miles near the picture edge, the apparent cumuliform cloud in a satellite photograph is actually a cluster of several clouds (except on rare occasions).

Band

A relatively solid (covered, "C", or mostly covered, "MCO") reflection from clouds, with a rectangular length-to-width ratio of at least 4:1.

Line

A series of aligned cloud elements nearly all of which are connected, with a general width of less than 1° (latitude).

Street

A series alignment of individual elements which are not interconnected. Usually there are several quasi-equidistant streets.

Striations

Approximately parallel streaks, each only a few miles in width, seen in an otherwise apparently smooth overcast area.

Direction-of-Shear of Cirrus

Double-shafted arrow that points from the heavy cloud elements in the direction of the cirrus "blow-off" plumes.

Eddy

Pattern formed either by cloud lines or bands which may indicate a weak circulation or swirl. The eddy pattern apparently is the result of weak large scale flow or of small scale effects, such as the disturbed flow to the lee of an island. In either case the cloud bands or lines will be nephed with lines indicating the cloud pattern.

Hazy

May be noted on a nephanalysis when a clear cloud pattern or terrain feature, as seen on a previous orbit, no longer appears to have the same clarity. (This condition may indicate the presence of very thin cirrus.)

Heavy

Very bright reflection from a cloud mass, i.e., the picture is saturated.

Thin

A translucent cloud area with other clouds or terrain seen beneath.

Cloud Cover Characteristics

Solid

Compact, with no breaks.

Solid with Streaks

Variations in brightness caused by apparent streaks in the reflection, but leaving no question that the area is all reflective.

Solid with Breaks

Breaks are of large scale, composed of clear or less bright areas due to multiple cloud decks.

Loose Weave

Rough textured, with or without pattern. Variation in reflection does not indicate complete absence of cloud in dull areas.

Cloud Edge Characteristics

Protrusions

Extensions from the otherwise linear edge of a cloud mass. These are usually triangular, but sometimes semi-circular in shape, and 2°-4° (latitude) across.

Ragged

Uneven, with marked changes in texture along cloud edge.

Sharp

An abrupt discontinuity in reflection. The edge is solid rather than ragged, but not necessarily straight.

Vortex

A pattern of one or more cloud bands spiraling into a center, indicating a definite center of circulation. (i.e. at least one closed contour for at least one level in conventional analysis.)

Vorticity Center

A weak vortex cloud pattern composed of cumuliform elements which is usually observed between the 500mb long wave ridge and associated downstream trough.

Vorticity Max or PVA Max [Not yet in use]

A covered, "C", bright, isolated, crescent-shaped middle/high cloud pattern which is 2° (latitude) or more in length. (This "MAX" is believed to represent an area of maximum positive vorticity advection and not a closed circulation.)

Circulation Center*

Cloud bands appear to form a fairly symmetrical pattern of arcs, which do not spiral into a definite center.

Fine Cells*

An area of small cumuliform elements having apparently moderate vertical development, with no spreading out of the cloud tops.

Inversion-Dominated*

An area of cumuliform elements whose vertical development is capped by an inversion. The tops of the cumulus elements spread out at the base of the inversion.

Vermiculated*

A distinctive pattern of cumuliform cloud elements thought to be formed in a stable layer of the lower atmosphere.

Probable

The photographic evidence is inconclusive or incomplete, but the interpretation is confirmed by current NMC analysis.

Possible

The picture does not present a clear-cut example of a recognizable pattern, and the interpretation is not supported by current NMC analysis.

*The use and definition of these terms are now being considered for possible revision by NWSC.